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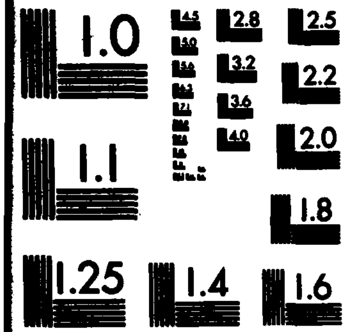


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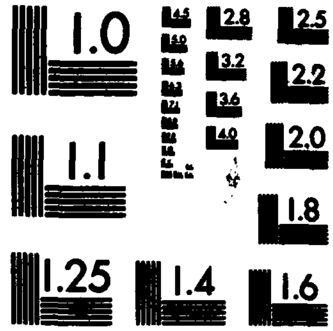


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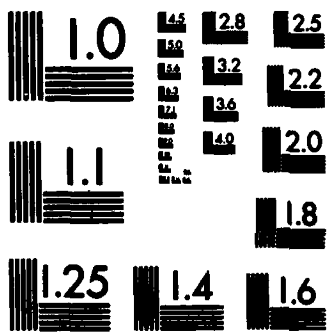


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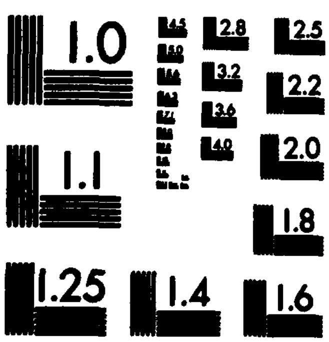


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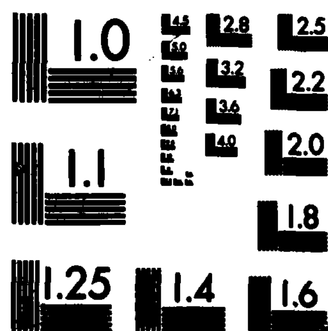


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RESEARCH AND DEVELOPMENT TECHNICAL REPORT
CORADCOM- 79-0789-7A

# MANUFACTURING METHODS AND TECHNOLOGY PROGRAM FOR RUGGEDIZED TACTICAL FIBER OPTIC CABLE

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SEVENTH PROGRESS REPORT
FOR PERIOD
JULY 1981 - SEPT 1981



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This project has been accomplished as part of the U.S. Army Manufacturing Methods and Technology Program which has as its objective the timely establishment of manufacturing processes, techniques, or equipment to insure the efficient production of current or future defense programs.

**MANUFACTURING METHODS AND TECHNOLOGY PROGRAM**

**FOR RUGGEDIZED TACTICAL FIBER OPTIC CABLE**

**SEVENTH PROGRESS REPORT**

Contract DAAK80-79-C-0789

For the Period July 1981-September 1981

Object of Study:
To Establish an Automated Production
Process for Ruggedized Tactical
Fiber Optic Cable

Approved for public release; distribution unlimited.

Prepared for:

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Procurement Directorate, Procurement Division D
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report covers the period from July 1981 through September 1981 of the manufacturing methods and technology program for ruggedized tactical fiber optic cable. The scope of this effort, as reported herein, includes the following tasks and achievements:

a. Obtained CECOM approval for Estane® 58309 polyurethane jacketing compound

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20. ABSTRACT (continued)

b. Selected optical fibers for 12 confirmatory samples

c. Fabricated 12 confirmatory sample cables AND

d. Evaluated optically, mechanically, and environmentally the confirmatory samples according to the test plan.



A

## SUMMARY

This report covers the period from July 1 to September 30, 1981, of the manufacturing methods and technology (MM&T) program for a ruggedized tactical fiber optic cable.

During this time frame CECOM approval was obtained for the use of B.F. Goodrich Estane® 58309 polyurethane as a replacement for Roylar® E-80. Ten cables of the confirmatory sample phase were fabricated and evaluated. During this phase three cables had to be remade due to equipment failures. The confirmatory sample cables passed all optical, environmental, and mechanical tests with the exception of the low temperature impact test.

TABLE OF CONTENTS (continued)

## 1.0 POLYURETHANE EVALUATION APPROVAL

An intensive study of a polyurethane jacketing compound was completed. This study was needed because the original compound manufacturer sold the polyurethane business line and the buyer had some difficulties reproducing the original jacketing compound. The study consisted of testing the polyurethane jacket for its effect on the mechanical properties of the cable and its effect on the optical performance of fibers at low temperature (-55°C).

Five short samples of cables with three different lot numbers and three different extrusion temperature profiles were fabricated and evaluated for impact, twist-bend, and flexure resistance at room temperature, at -55°C, and at +71°C. Two long cables were also tested for impact resistance at -55°C. These tests demonstrated that Estane® 58309 BLK-289 meets the mechanical requirements of MM&T-789898.

Three cables were fabricated for optical evaluation (attenuation and dispersion). The attenuation was measured at room temperature and at -55°C. Two of these cables met the -55°C attenuation goal demonstrating that Estane® 58309 BLK-289 does not appreciably affect the optical performance characteristics of fibers at that temperature.

The polyurethane jacket compound study was completed prior to the fabrication and evaluation of 12 confirmatory sample cables to ensure compliance with specification MM&T-789898.

On July 1, 1981, personnel from ITT EOPD visited CECOM and presented the results of the polyurethane evaluation task. CECOM approved the compound selected by ITT EOPD (B.F. Goodrich's Estane® 58309 BLK-289). The following changes to the program were agreed upon

a. Change from Roylar® E-80 to Estane® 58309 polyurethane

b. Slip delivery of the confirmatory sample cables from 29 June to 31 August

c. Slip delivery of the pilot run from 27 October to 18 December

The CECOM representatives accepted these changes with the provision that ITT EOPD provide the following compensation:

a. Color code fibers (ink is acceptable)

b. Include an addendum in the confirmatory sample test plan to cover the test setup for the twist-bend test. This was the problem area due to operator interpretation of procedures which led to failures

c. Add one quarterly report for period ending 31 October 1981

ITT EOPD accepted these compensations and was given a verbal go-ahead.

CECOM representatives were concerned about the surface finish of the cable. As a result, they wanted as dull a finish as possible. Since, however, a dull surface finish was not specified in the contract and since the effect of any modification on the performance characteristics of polyurethane is unknown, ITT EOPD agreed only to explore the possibility of providing a dull finish in the future.

## 2.0 FIBER SELECTION

Fibers used for the fabrication of 12 confirmatory sample cables were selected based on the following ITT specifications at room temperature before cabling:

| | | |
|---|---|---|
| a. | Fiber core | 50 μm ±5 μm |
| b. | Fiber outside diameter (od) | 125 μm ±6 μm |
| c. | Attenuation at 0.82 μm | <4.5 dB/km |
| d. | Dispersion at 0.82 μm | <1.7 ns/km |
| e. | Numerical aperture (NA) (90% power) | >0.17 |
| f. | Proof-test | 689.5 MPa |
| g. | Dow Corning Sylgard® 184 buffer | 0.3 mm |
| h. | Hytrel® 7246 jacket | 0.9 mm |
| i. | Fiber length | 1.1 km |

These specific**ions were chosen to take into account cabling excess loss, dispersion changes during cabling and startup, and end losses experienced during fiber and cable jacketing.

## 3.0 FABRICATION OF CONFIRMATORY SAMPLE CABLES

Twelve confirmatory cables were fabricated. Figure 3.0-1 shows the cable configuration fabricated. Three cables failed and will have to be replaced.

One cable failed extrusion of the final jacket. Two temperature controllers which control extruder barrel heat zones malfunctioned. This malfunction resulted in a viscosity change of the plastic and, hence, a change in cable jacket diameter fluctuation. The final length of the cable was 989 m. The second cable was rejected for a broken fiber approximately 600 m from the end. The third cable was rejected for jacket damage during high temperature testing. The controller governing the temperature of the test chamber malfunctioned and allowed the temperature to rise above the set point. This malfunction was corrected by installing a controller that can be adjusted to a few degrees above the test temperature and will shut off the unit if the set point temperature is reached.

One of the three replacement cables has been fabricated and tested. The fibers for the remaining two cables are being selected and evaluated.

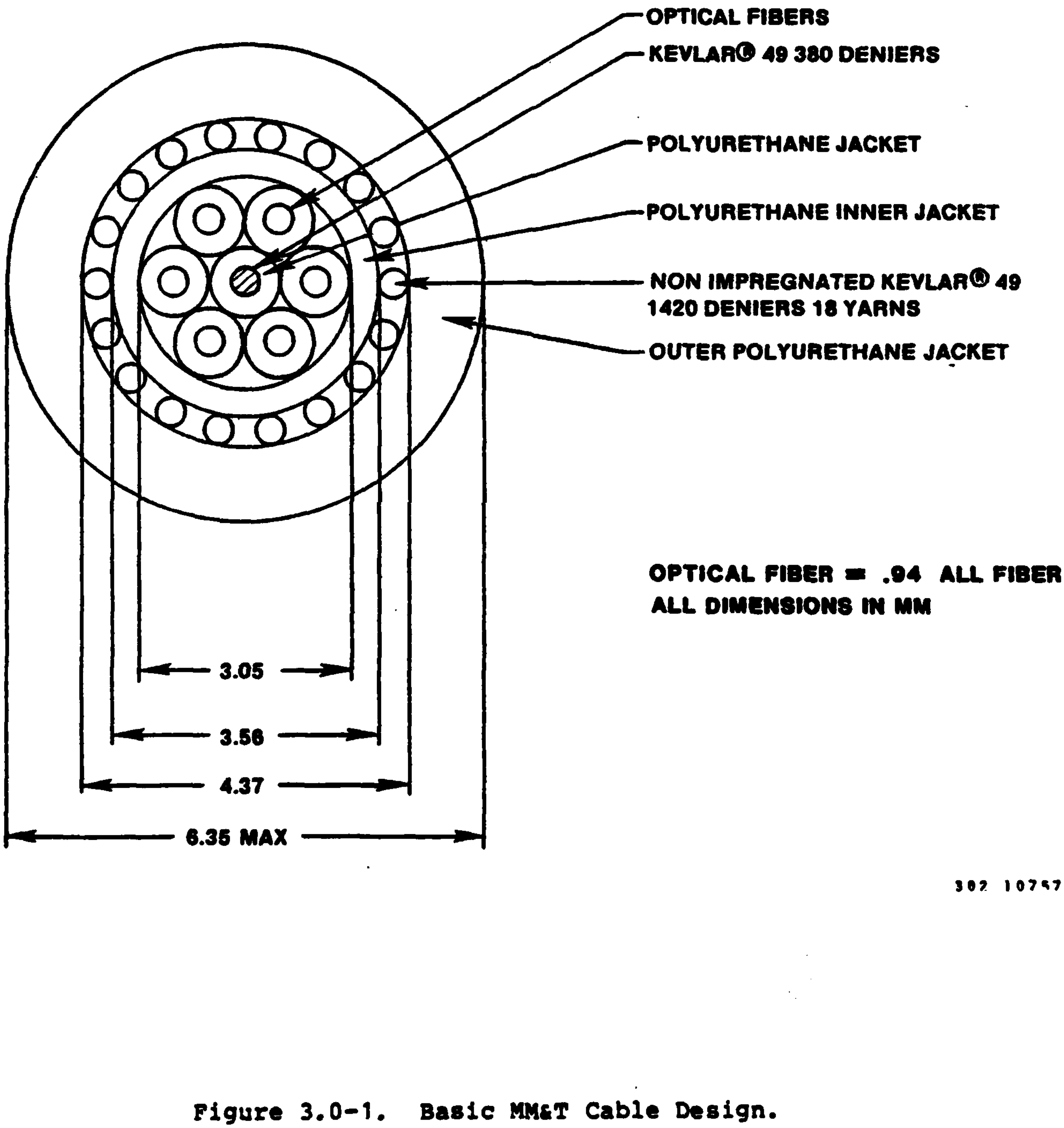


Figure 3.0-1. Basic MM&T Cable Design.

## 4.0 EVALUATION OF CONFIRMATORY CABLES

The results of optical, environmental, and mechanical tests performed on confirmatory cables are described on the following pages.

### 4.1 Confirmatory Sample Preproduction Lot

The confirmatory sample preproduction test lot consists of 12 1-km cables wound on DR-5 reels. The mechanical test samples were selected from 3 of the 12 reels. Environmental test samples consisted of 1-km cables wound on DR-5 reels, with the exception of short samples for the fungus tests. Of the remaining nine cables, three were exposed to all environmental tests. Three cables were allocated individually for one of the three environmental tests. A total of four samples were evaluated in each test. The samples were selected and allocated at random. Refer to Figure 4.1-1 for the preproduction test procedure flow chart. Tables 4.1-1 and 4.1-2 outline the test performed on each individual cable.

### 4.2 Optical Test

#### 4.2.1 Attenuation Test

The attenuation tests were performed by the cutback method. This procedure is described in the test report for phase 3 MM&T cables in Appendix A. The optical attenuation of each cabled fiber was measured at six selected wavelengths: 8,200; 8,500; 10,600;

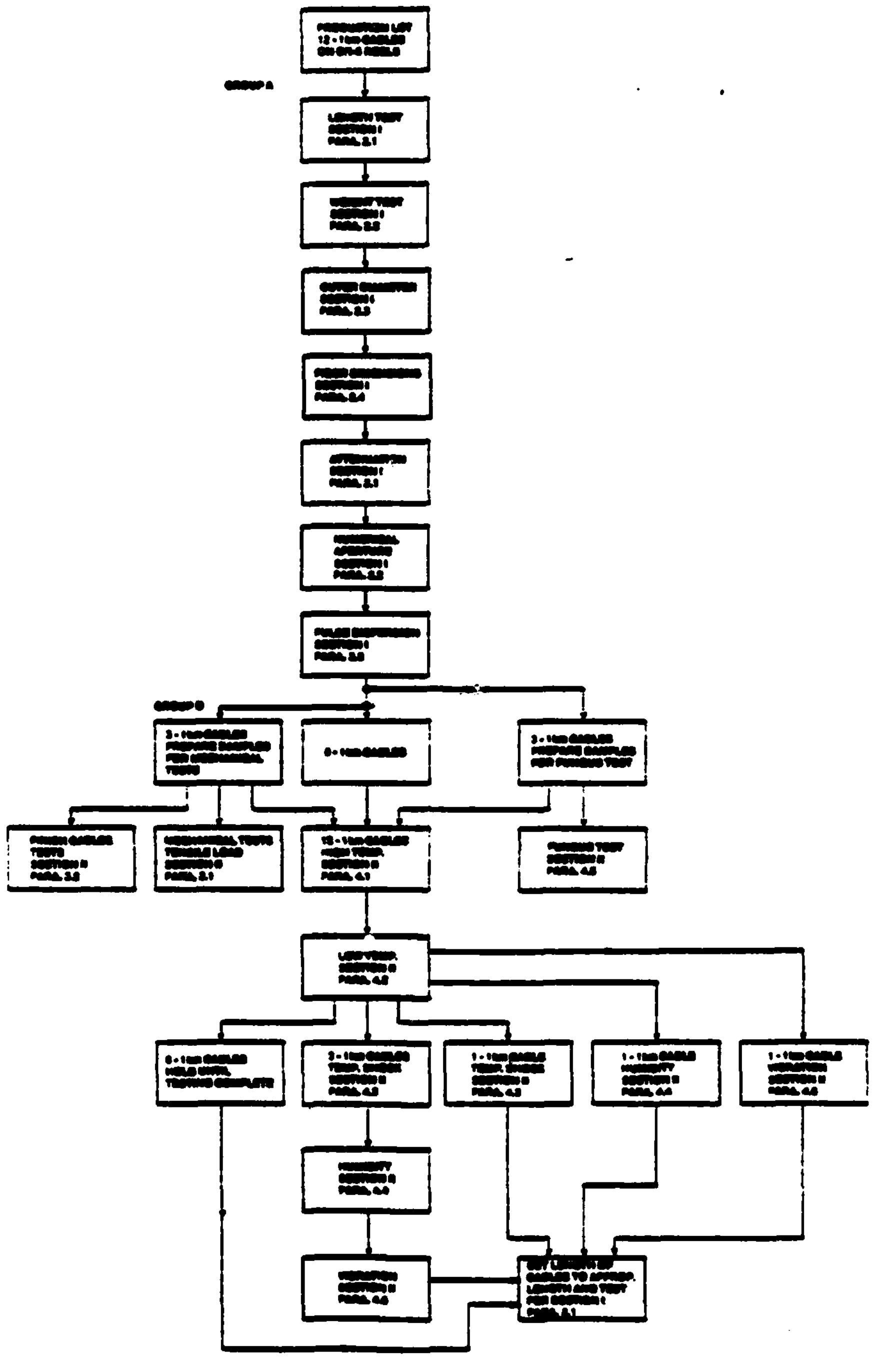

Figure 4.1-1. Preproduction Test Procedure.

Table 4.1-1. Confirmatory Sample Cables.

| Cable Number | Batch Number |
|---|---|
| 1 | 071781-4C-1 |
| 2 | 071881-4C-1 |
| 3 | 071881-4C-2 |
| 4 | 071881-4C-3 |
| 5 | 072081-4C-1 |
| 6 | 071681-4C-1 |
| 7 | 072081-4C-2 |
| 8 | 082781-4C-1 |
| 10 | 091881-4C-2 |
| 12 | 091781-4C-1 |

Table 4.1-2. Cable MM&T Confirmatory Samples.

| | Cable Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| DR-5 reels | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Length test | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Weight test | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Outer diameter | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Fiber dimensions | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Atten (various wavelengths and NA) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| NA | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Pulse dispersion | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Mechanical tests (tensile load) | - | - | ✓ | - | ✓ | - | ✓ | - | - | - | - | - |
| Finish cable test | - | - | ✓ | - | ✓ | - | ✓ | - | - | - | - | - |
| Fungus test | - | ✓ | - | - | ✓ | - | ✓ | - | - | - | - | - |
| High temperature | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Low temperature | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

Table 4.1-2. Cable MM&T Confirmatory Samples (continued).

| | Cable Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Temperature shock | – | ✓ | – | – | ✓* | ✓ | ✓ | – | – | – | – | – |
| Humidity | – | ✓ | – | ✓* | – | ✓ | ✓ | – | – | – | – | – |
| Vibration | – | ✓ | – | – | – | ✓ | ✓ | ✓* | – | – | – | – |
| Cut to length | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

*Control cable.

11,000; 12,000; and 13,000 Å. All the cable samples were tested to meet the <5 dB/km attenuation requirement.

The calculation procedure followed Method 6020 of MIL-STD-1678. The output through the fiber was measured at 0.82 μm for injection numerical apertures of 0.89, 0.124, 0.176, and 0.243. The attenuation at each of the remaining five wavelengths was measured at an injected NA of 0.089. The single injection NA was selected to avoid changing injection NA conditions at each wavelength thereby eliminating input variation between the short and long length measurements.

Once the output through the long length was measured at the specified wavelengths, the fiber was cut at a distance of 1 m from the injection end. A new end was prepared on the output end of the reference length and the measurement repeated for the short length. The attenuation test setup is shown in Figure 4.2.1-1.

The attenuation of each test fiber at all six wavelengths with an input NA of 0.089, except at 0.827 μm where four injection NA values were used, is reported. All fibers tested passed the specification. Results are recorded in Appendix A.

### 4.2.2 Pulse Dispersion

All confirmatory cables were tested for pulse dispersion to

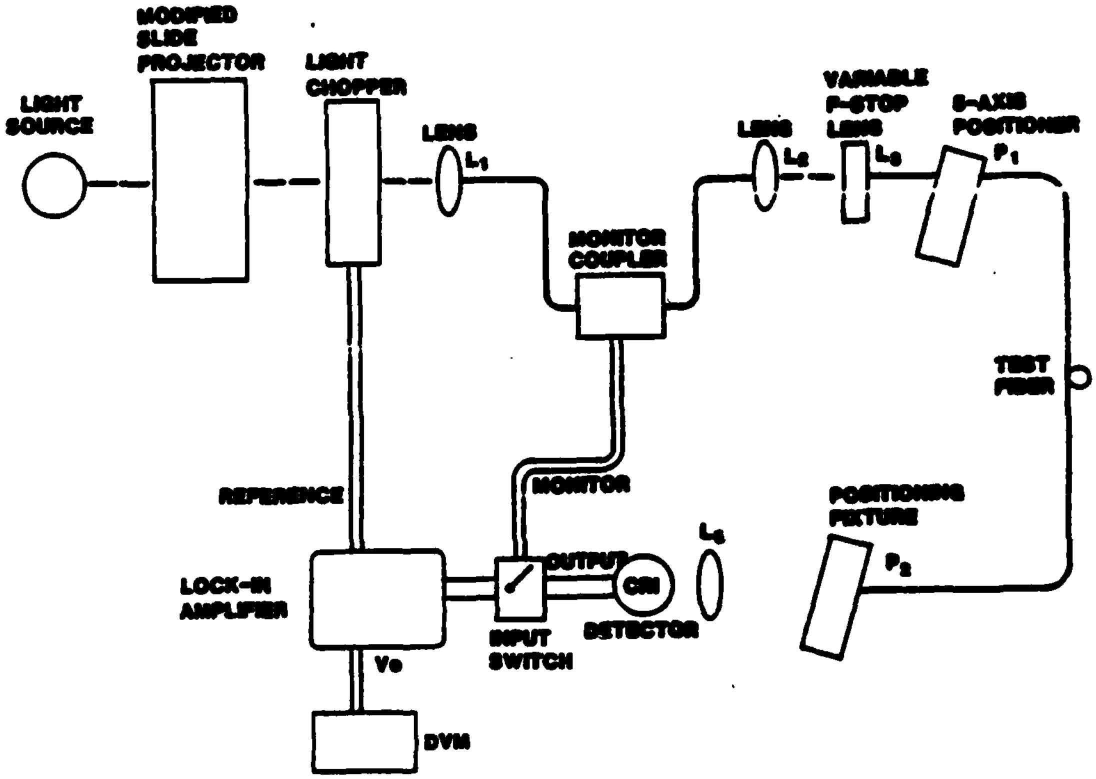


Figure 4.2.1-1. Attenuation Test Setup.

determine if the requirement of 2 ns/km maximum was met. The 50% (3 dB) optical pulse dispersion of the test fiber was measured using existing equipment (Figure 4.2.2-1) operating at 9000 Å. Method 6050 of DOD-STD-1678 was utilized. The 50% pulse dispersion requirements of optical fibers were met. The results of the testing of optical fibers are recorded in Appendix A.

### 4.2.3 Numerical Aperture (NA)

All confirmatory cables were tested to determine if the NA requirement of >0.17 was met. The exit NA, defined as sin $\phi/2$ where $\phi$ is the core angle containing 90% of the output power of each cabled fiber, was measured at a wavelength of 0.82 μm. The required NA specification was met for each optical fiber and is reported in Appendix A. The NA station is illustrated in Figure 4.2.3-1.

## 4.3 Environmental Test

Environmental test samples consisted of 1-km cables wound on DR-5 reels, with the exception of short samples for the fungus tests. All 12 reels were subjected to high and low temperature cycling. Six cables were allocated individually for one of the six environmental tests (fungus, humidity, temperature shock, and vibration). A total of seven samples was evaluated in each test. All samples were selected and allocated at random.

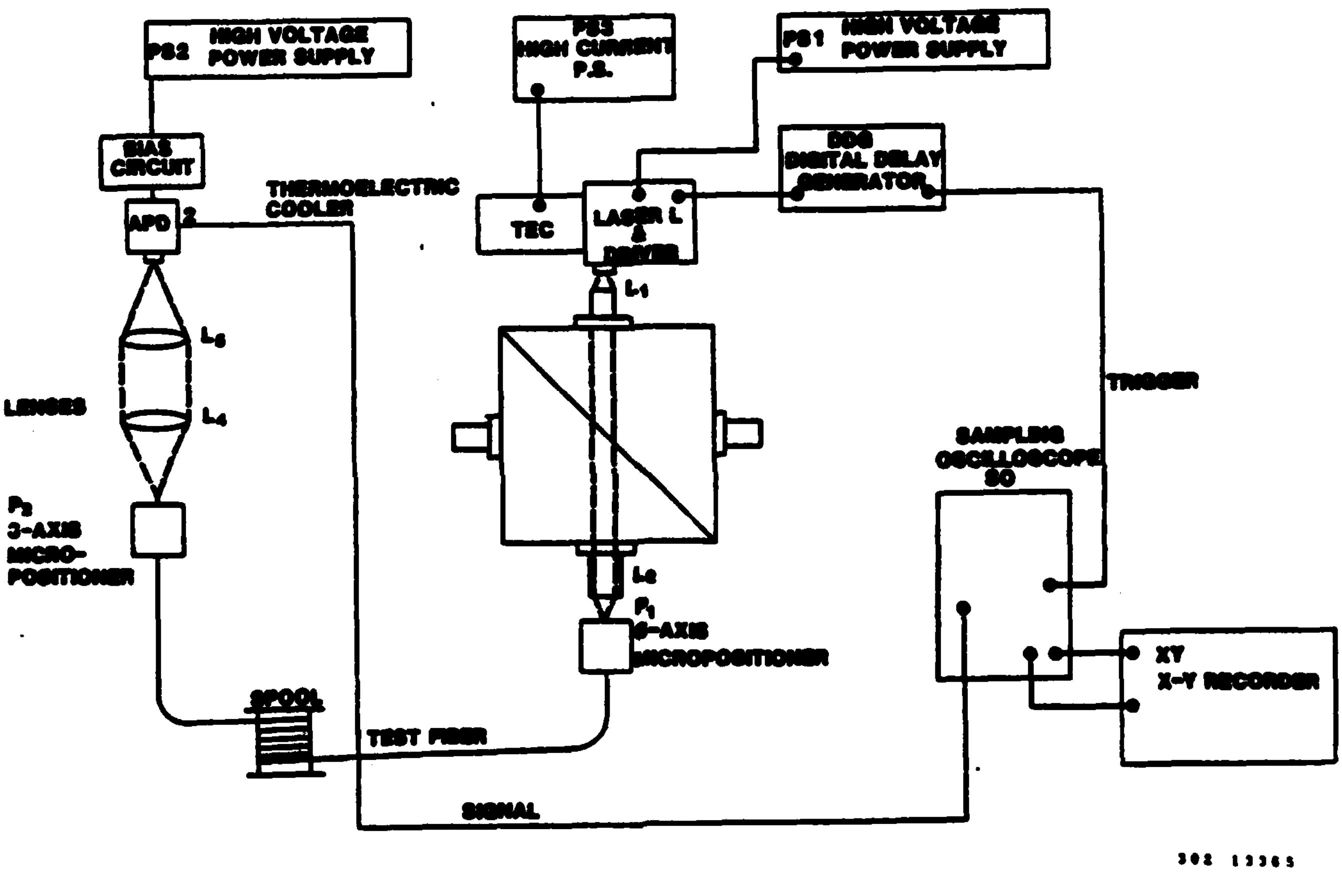


Figure 4.2.2-1. Pulse Dispersion Test Setup.

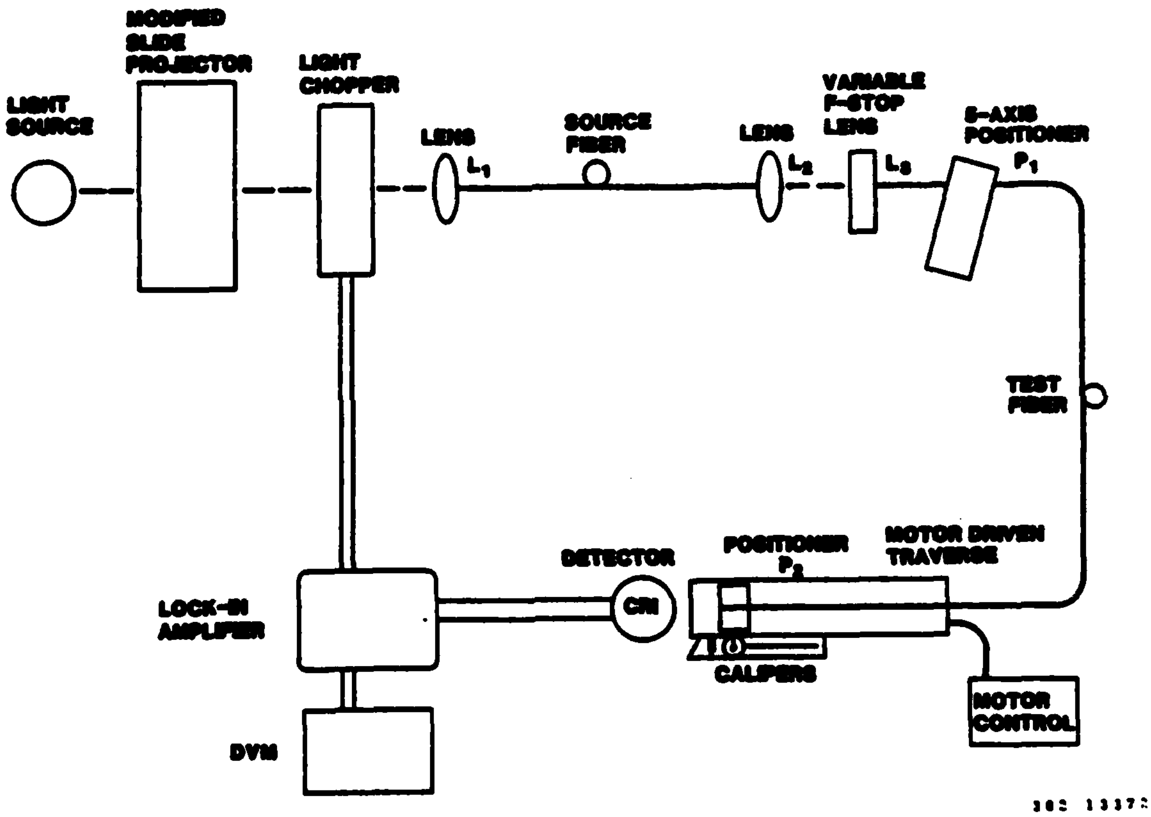


Figure 4.2.3-1. Test Setup of 90% Power Numerical Aperture (NA).

#### 4.3.1 Fungus Test

Fungus testing was conducted in accordance with MIL-STD-810B, Method 508.1, Procedure I, at the Aerospace Research Corp. in Roanoke, Virginia. The samples contained small unrelated colonies of fungus. A very light surface growth was evident but was easily wiped clean with a dry paper towel (per specification). The fungus test was successfully met and the results are described in Appendix B.

#### 4.3.2 High Temperature Cycle

Each cable sample was tested in accordance with MIL-STD-810, Method 501.1, Procedure II, except that steps 7 and 8 were omitted per program requirements and paragraph 4.1 of the preproduction procedures for ruggedized tactical fiber optic cable, ITT Doc Id No 80-29-09, Revision III. There was no breakage of individual fibers or other visible cable damage and all cables met the optical requirements. The optical results are recorded in Appendix G.

#### 4.3.3 Low Temperature Cycle

The cable samples were tested in accordance with MIL-STD-810, Method 502.1, Procedure I, except that steps 4 and 5 were omitted and paragraph 4.2 of the MM&T preproduction test procedure for ruggedized tactical fiber optic cable, ITT Doc Id No 80-29-09, Revision III. There was no visible cable damage and there were no broken fibers. The low temperature cycle test passed and optical results are reported in Appendix G.

#### 4.3.4 Humidity Cycle

Four cables were subjected to the humidity cycle in accordance with MIL-STD-810, Method 507.1, Procedure II, and paragraph 4.4 of the MM&T preproduction test plan for ruggedized tactical fiber optic cable, ITT Doc Id No 80-29-09, Revision III. The four cable samples were evaluated for attenuation, dispersion, and 90% power NA after humidity test. There was no visible cable damage and no broken fibers and the cables met all optical requirements. The optical results are reported in Appendix C.

#### 4.3.5 Vibration Test

Four 1-km cables were subjected to secured cargo and loose cargo tests during the vibration phase. The vibration tests were conducted in accordance with paragraph 4.6 of the preproduction test procedure for ruggedized tactical fiber optic cable, ITT Doc Id No 80-29-09, Revision III. The attenuation for each cable at the specified wavelengths was measured along with the dispersion and 90% power NA with no significant change. No damage to the cable or reel occurred during the test. The vibration test was successfully met and test results are recorded in Appendix D.

#### 4.3.6 Temperature Shock

Four cable samples were subjected to the temperature shock cycle in accordance with MIL-STD-810, Method 503.1, and paragraph 4.3 of the preproduction test procedures for ruggedized tactical fiber

optic cable, ITT Doc Id No 80-29-09, Revision III. The four cable samples were evaluated for attenuation, dispersion, and 90% power NA after this test with excellent results. All requirements were met and test results are recorded in Appendix E.

### 4.4 Finished Cable Test

Three cable samples were subjected to static tensile load and mechanical test. The cables were subjected to a static tensile load and impact, twist-bend at room temperature, high temperature (+71°C), and low temperature (-54°C).

#### 4.4.1 Static Tensile Load Test

Three cable samples were subjected to a static tensile load of 1780 N (400 $lb_f$) in accordance with paragraph 3.1 of the preproduction test procedure for ruggedized tactical fiber optic cable, ITT Doc Id No 80-29-09, Revision III. There was no breakage of individual fibers or visible cable damage within the gage length. The static tensile load test passed requirements and test results are recorded in Appendix F.

#### 4.4.2 Mechanical Test

Three 15-m lengths were cut from test cables for the mechanical testing. The cables were subjected to impact, twist, and bend tests at room temperature, high temperature (+71°C), and low temperature (-54°C). Impact testing was performed at a loading of 3 ft·$lb_f$. The load mass for twist and bend was 22 $lb_m$ (10 kg).

The cable samples were tested in accordance with the preproduction test procedure for ruggedized tactical fiber optic cable, ITT Doc Id No 80-29-09, Revision III.

#### 4.4.2.1 Impact Test

Three 15-m lengths of test cable were subjected to impact test at room temperature, +71°C, and -54°C. These cables were tested in accordance with paragarph 3.2.1 of the preproduction test procedure for ruggedized tactical fiber optic cable, ITT Doc Id No 80-29-09, Revision III, and DOD-STD-1678, Method 2030, Procedure I. Impact testing was performed at a loading of 3 $ft \cdot lb_f$. The cable samples passed all the tests except low temperature impact. This failure is being investigated in detail. All test cables successfully passed the twist test. The results of the impact testing are recorded in Appendix F.

#### 4.4.2.2 Twist Test

Three 15-m lengths of test cable were subjected to twist test at room temperature, +71°C, and -54°C. These cables were tested in accordance with paragraph 3.2.2 the preproduction test procedure for ruggedized tactical fiber optic cable, ITT Doc Id No 80-29-09, Revision III, and DOD-STD-1678, Method 2060, Procedure I. The load mass for the twist test was 22 $lb_m$ (10 kg). There was no visible cable damage and there were no broken fibers. All test cables successfully passed the twist test. The results of the twist test are recorded in Appendix F.

#### 4.4.2.3 Bend Test

Three 15-m lengths of test cable were subjected to bend test at room temperature, +71°C, and -54°C. These cables were tested in accordance with paragraph 3.2.3 of the preproduction test procedure for ruggedized tactical fiber optic cable, ITT Doc Id No 80-29-09, Revision III, and DOD-STD-1678, Method 2010, Procedure I. The load mass for the bend test was 22 $lb_m$ (10 kg). There was no visible cable damage and there were no broken fibers. All cable samples passed the test. The results of the bend test are recorded in Appendix F.

## 5.0 CABLE MANUFACTURING PROCESS, EQUIPMENT, TOOLING, AND MEASUREMENTS

This section describes the manufacturing process, equipment and tooling used to manufacture the MM&T cable as well as optical evaluation of the cables.

### 5.1 Cable Manufacturing Process

The basic MM&T cable design is shown in Figure 5.1-1. The cable fabrication flow chart is shown in Figure 5.1-2.

The MM&T cable optical core contains six optical fibers contrahelically laid around a polyurethane coated Kevlar® central member. A jacket of polyurethane is extruded over the optical core. Then the jacketed optical core is served with 18 Kevlar® strength members before a final jacket of polyurethane is applied.

#### 5.1.1 Fiber Rewind Station

This station (Figure 5.1-2, Operation E1) is used to respool and inspect fibers in preparation for the subsequent stranding operation. The equipment consists of a rewinder, an optical lump detector to examine the fiber buffer jacket for any nonuniformities, and a constant-tension compensating payoff to eliminate fiber breaks.

This unit is also used to visually inspect fibers for buffer jacket flaws.

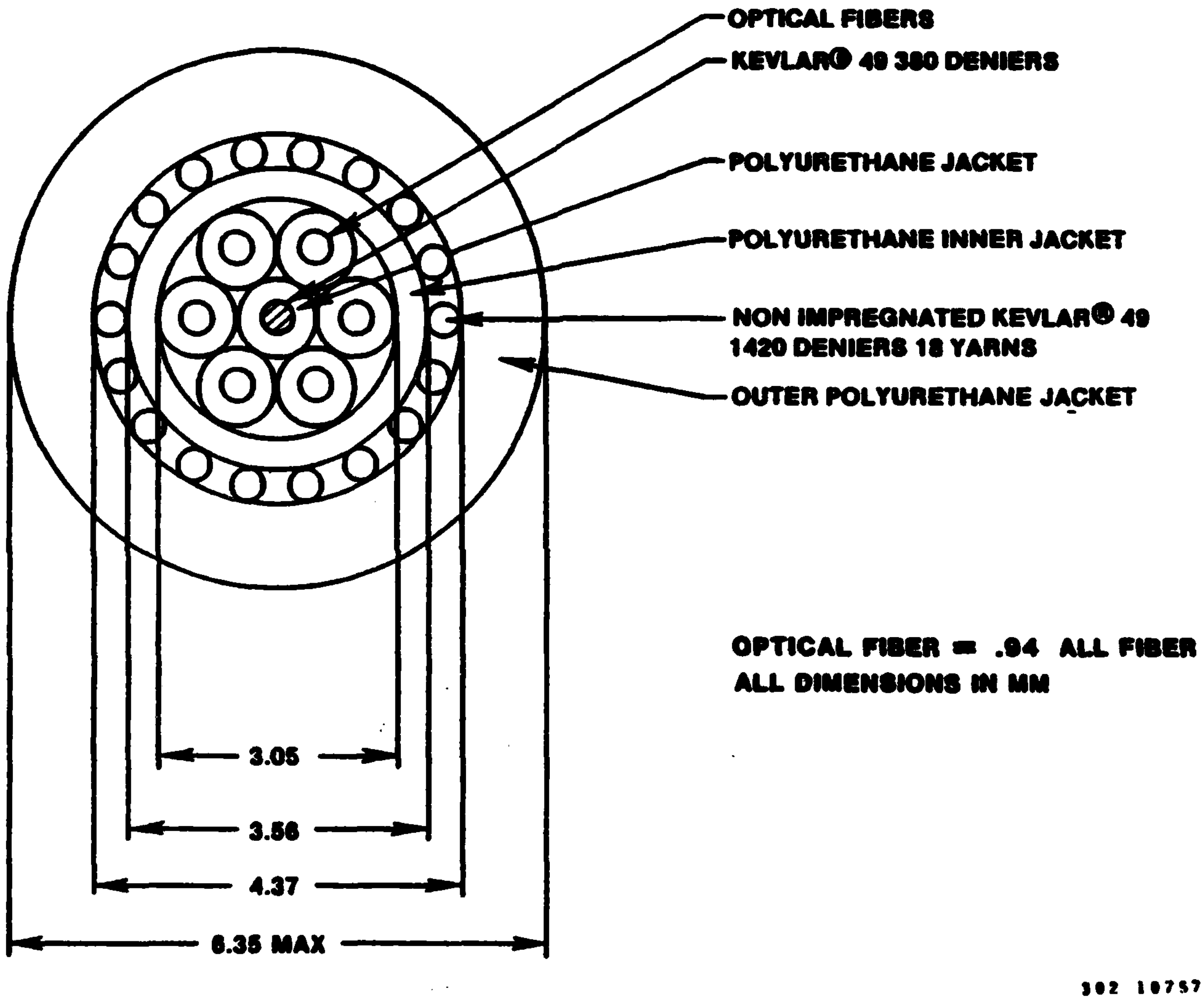


Figure 5.1-1. Basic MM&T Cable Design.

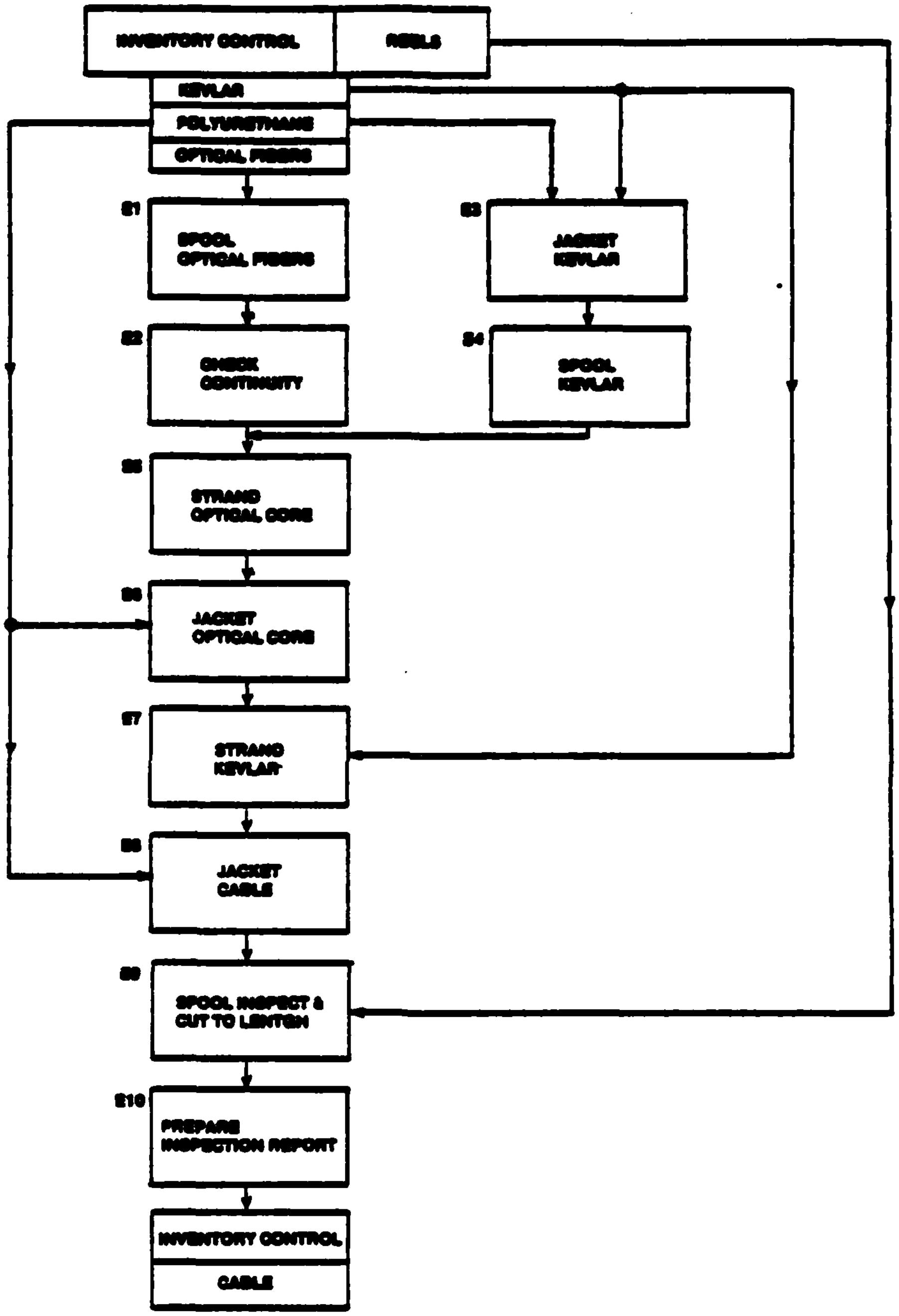


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Figure 5.1-2. Cable Fabrication Flow Chart.

### 5.1.2 Fiber Continuity Check Station

Before fibers are stranded into a cable bundle, continuity of each fiber is tested and any defects or broken fibers are removed. The unit used at this station (Figure 5.1-2, Operation E2) is an instrument designed for detecting and locating faults in optical fibers, for measuring their length, and for analyzing their transmission characteristics. The instrument operates by launching a pulse of laser light into the fiber and monitoring the amplitude and time delay of events in the light reflected back along the fiber.

### 5.1.3 Kevlar® Jacketing Station

This station (Figure 5.1-2, Operation E3) is used to overcoat a Kevlar® 49-380 denier yarn with a polyurethane jacket which is used as the central core for the optical bundle. A 1-in extruder is used to pressure extrude the polyurethane jacket at a rate of 76 m/min. An automatic diameter control unit is used, which measures the extruded jacket diameter of the core element and regulates the line speed to provide a constant diameter over the existing cable length.

### 5.1.4 Respooling Station for Polyurethane Jacketed Kevlar® Central Strength Member

The identical equipment as used for the fiber rewind operation (paragraph 5.1.1) is employed. The capacity of this unit is ample to perform both fiber rewind and central strength member respooling operations.

### 5.1.5 Optical Core Stranding Station

This station is used (Figure 5.1-2, Operation E5) to strand six optical fibers helically around the polyurethane Kevlar® jacketed central stength member. A high speed single twist closing unit equipped with a 13-bay neutralizing unit is employed. The unit operates at 1800 m/h.

### 5.1.6 Optical Core Jacketing Station

Station E6, Figure 5.1-2, is used to extrude the polyurethane jacket over the optical core. The jacket is applied with a 1-1/2-in extrusion line capable of extruding the first jacket at 68 m/min.

### 5.1.7 Kevlar® Stranding Station

Station E7, Figure 5.1-2, is employed to strand 18 Kevlar® strength members around the jacketed optical core. The Kevlar® stranding machine contrahelically serves the 18 Kevlar® strength members around the optical core. The Kevlar® serving line is capable of stranding Kevlar® at 20 m/min.

### 5.1.8 Final Jacketing Station

A 2-in extrusion line (Figure 5.1-2, Operation E8) is used to extrude the final cable jacket. The extrusion line is capable of extruding the final jacket at 42 m/min which is double the rate required for the MM&T program.

5.1.9 Final Cable Respooling Station

The cable is respooled on the Federal cable rewinder (Figure 5.1-2, Operation E9) for shipping. This machine enables an inspector to visually inspect the cable for anomalies and irregularities while being spooled on the DR-5 reels.

## 6.0 SUMMARY OF ACCOMPLISHMENTS

The objectives of the work performed during this quarter were to (a) obtain approval from CECOM for the use of B.F. Goodrich Estane® 58309 as a replacement polyurethane for Roylar® E-80 and (b) fabricate and evaluate confirmatory sample cables.

The approval for use of the Estane® 58309 was given during a meeting with ITT EOPD and CECOM representatives on July 1, 1981, at Fort Monmouth, New Jersey. The approval was given on the provision that ITT EOPD would provide the following compensation:

a. Color code MM&T fibers

b. Include a change page in the confirmatory sample test plan to cover the test setup for the twist-bend test

c. Add monthly reports until program completion

d. Add one quarterly report for the period ending 31 October 1981

Twelve confirmatory cables were fabricated. Three cables failed and will be replaced. One cable failed during extrusion of the final jacket. Two temperature controllers that determine the temperature of the extruder barrel malfunctioned. This malfunction changed the viscosity of the plastic, causing bridging in the extruder. Bridging causes an uneven plastic flow which results in cable diameter fluctuation. The final length of this cable was 989 m. The second cable was disqualified for a broken fiber approximately 600 m from the end. The third cable was being high

temperature tested when the voltage regulator for the electronic circuit changed values. The result was an increase in the temperature of the test chamber, causing damage to the cable jacket.

All optical, environmental, and mechanical tests performed on confirmatory cable samples were successfully completed with the exception of the low temperature impact test. Cable samples tested at 3 ft·lb and -55°C resulted in one or more broken fibers. This failure is being investigated in detail.

## 7.0 PERSONNEL

The personnel involved in the cable MM&T program, their responsibilities, and their hours expended on the program during this period are listed in Table 7.0-1.

Table 7.0-1. Personnel Working on the MM&T Program.

| Name | Responsibility | Man-Hours Expended |
|---|---|---|
| R. Coon | Program management | 66 |
| J. Smith | Senior project engineer | 44 |
| D. Taylor | Cable production | 143 |

Table 7.0-2. Man-Hours Expended Compared With Plan.

| Proposed | Program Manager | Engineer | Manufacturing | Support | Total |
|---|---|---|---|---|---|
| Program to date | 540 | 7,144 | 4,120 | 1,000 | 12,804 |
| **Actual** | | | | | |
| This period | 76 | 102 | 1,627 | - | 1,805 |
| Program to date | 727 | 5,393 | 4,854 | 273 | 11,247 |

## 8.0 PROGRAM FOR NEXT QUARTER

The program for the next quarter includes the following objectives:

a. Complete fabrication and evaluation of confirmatory cables.

b. Investigate low temperature impact failure.

c. Select optical fibers for pilot run.

d. Submit monthly progress reports.

# APPENDIX A

# OPTICAL TEST DATA

Table A-1. Dimensional Measurements.

| Fiber Identification | Core Diameter (μm) SOP* | Core Diameter (μm) EOP** | Cladding Diameter (μm) SOP* | Cladding Diameter (μm) EOP** |
|---|---|---|---|---|
| **Cable 1: 071781-4C-1** | | | | |
| 1 Blue | 51 x 50 | 45 x 48 | 126 | 126 |
| 2 Orange | 51 x 50 | 45 x 48 | 126 | 126 |
| 3 Brown | 49 | 49 | 128 | 126 x 124 |
| 4 White | 51 x 50 | 49 x 48 | 124 | 123 x 122 |
| 5 Slate | 53 | 53 x 52 | 126 | 124 |
| 6 Green | 53 x 52 | 51 x 54 | 125 | 126 |
| **Cable 2: 071881-4C-1** | | | | |
| 1 Blue | 51 x 50 | 51 x 50 | 124 x 123 | 124 x 122 |
| 2 Orange | 51 | 52 x 51 | 125 x 124 | 123 x 122 |
| 3 Brown | 53 x 52 | 53 | 126 | 126 |
| 4 White | 53 | 53 x 52 | 126 | 124 |
| 5 Slate | 49 x 47 | 51 x 50 | 126 | 127 x 126 |
| 6 Green | 49 | 50 | 126 | 128 x 126 |

* Start of pull, bottom spool.
** End of pull, top of spool.

Table A-1. Dimensional Measurements (continued).

| Fiber Identification | | Core Diameter (μm) SOP* | Core Diameter (μm) EOP** | Cladding Diameter (μm) SOP* | Cladding Diameter (μm) EOP** |
|---|---|---|---|---|---|
| **Cable 3: 071881-4C-2** | | | | | |
| 1 | Blue | 50 x 48 | 47 x 45 | 126 x 125 | 126 |
| 2 | Orange | 50 x 49 | 50 x 49 | 125 x 124 | 125 x 124 |
| 3 | Brown | 47 x 45 | 48 | 126 | 126 |
| 4 | White | 50 | 49 x 46 | 124 x 123 | 125 x 124 |
| 5 | Slate | 51 x 49 | 51 x 49 | 126 x 124 | 125 x 124 |
| 6 | Green | 51 x 50 | 51 x 50 | 124 x 123 | 124 x 122 |
| **Cable 4: 071881-4C-3** | | | | | |
| 1 | Blue | 49 x 48 | 49 x 48 | 127 x 124 | 126 |
| 2 | Orange | 50 x 47 | 50 x 47 | 126 x 125 | 126 x 124 |
| 3 | Brown | 53 | 51 x 50 | 126 x 124 | 126 x 124 |
| 4 | White | 49 x 46 | 52 x 51 | 127 x 126 | 127 x 125 |
| 5 | Slate | 53 x 52 | 51 x 54 | 125 | 126 |
| 6 | Green | 50 x 49 | 49 x 48 | 126 x 125 | 126 x 125 |

* Start of pull, bottom spool.
** End of pull, top of spool.

Table A-1. Dimensional Measurements (continued).

| Fiber Identification | Core Diameter (μm) SOP* | Core Diameter (μm) EOP** | Cladding Diameter (μm) SOP* | Cladding Diameter (μm) EOP** |
|---|---|---|---|---|
| **Cable 5: 072081-4C-1** | | | | |
| 1 Blue | 49 x 48 | 50 x 48 | 124 x 123 | 126 x 124 |
| 2 Orange | 52 x 53 | 51 x 52 | 123 x 124 | 124 x 125 |
| 3 Brown | 48 | 50 x 48 | 126 x 125 | 126 |
| 4 White | 52 x 51 | 52 x 50 | 126 x 124 | 126 x 124 |
| 5 Slate | 49 x 48 | 50 x 49 | 125 x 126 | 126 |
| 6 Green | 52 x 50 | 50 x 49 | 127 | 127 x 126 |
| **Cable 6: 071681-4C-1** | | | | |
| 1 Blue | 50 x 47 | 49 x 46 | 126 x 124 | 126 x 124 |
| 2 Orange | 49 x 46 | 46 | 125 x 124 | 125 x 124 |
| 3 Brown | 50 x 49 | 50 x 49 | 125 x 124 | 124 x 123 |
| 4 White | 51 x 50 | 53 | 126 x 124 | 126 x 125 |
| 5 Slate | 49 x 47 | 49 x 48 | 123 x 122 | 124 |
| 6 Green | 51 x 50 | 51 x 50 | 128 | 128 x 127 |

* Start of pull, bottom spool.
** End of pull, top of spool.

Table A-1. Dimensional Measurements (continued).

**Cable 7: 072081-4C-2**

| Fiber Identification | | Core Diameter (μm) | | Cladding Diameter (μm) | |
|---|---|---|---|---|---|
| | | SOP* | EOP** | SOP* | EOP** |
| 1 | Blue | 53 x 52 | 53 x 51 | 128 x 127 | 127 x 126 |
| 2 | Orange | 48 | 50 x 48 | 126 x 125 | 126 |
| 3 | Brown | 54 x 51 | 54 x 51 | 129 | 127 x 126 |
| 4 | White | 48 x 47 | 49 x 49 | 127 x 126 | 125 x 123 |
| 5 | Slate | 50 x 49 | 50 x 48 | 126 x 125 | 124 x 123 |
| 6 | Green | 49 | 50 x 49 | 126 | 125 |

**Cable 8: 082781-4C-1**

| | | | | | |
|---|---|---|---|---|---|
| 1 | Blue | 48 x 46 | 48 x 47 | 126 x 125 | 127 x 126 |
| 2 | Orange | 52 x 50 | 54 x 53 | 126 | 126 x 125 |
| 3 | Brown | 53 x 51 | 50 x 48 | 126 | 127 x 126 |
| 4 | White | 52 x 51 | 51 | 126 x 124 | 126 x 123 |
| 5 | Slate | 51 x 50 | 50 x 49 | 127 x 127 | 127 x 126 |
| 6 | Green | 52 x 51 | 51 x 50 | 126 x 125 | 126 |

* Start of pull, bottom spool.
** End of pull, top of spool.

Table A-1. Dimensional Measurements (continued).

Cable 10: 091881-4C-2

| | | | | | |
|---|---|---|---|---|---|
| 1 | Blue | 50 x 49 | 52 x 51 | 128 x 127 | 126 |
| 2 | Orange | 50 x 49 | 49 x 48 | 124 | 123 x 122 |
| 3 | Brown | 52 x 51 | 52 x 51 | 126 | 126 |
| 4 | White | 52 x 51 | 51 x 51 | 126 | 126 |
| 5 | Slate | 48 x 50 | 50 x 51 | 123 x 124 | 125 x 127 |
| 6 | Green | 55 x 52 | 51 x 50 | 126 x 124 | 127 x 125 |

* Start of pull, bottom spool.
** End of pull, top of spool.

Table A-1. Dimensional Measurements (continued).

Cable 12: 091781-4C-1

| | | | | | |
|---|---|---|---|---|---|
| 1 | Blue | 49 x 50 | 50 x 51 | 124 x 126 | 124 x 125 |
| 2 | Orange | 51 x 50 | 49 x 48 | 125 x 124 | 124 x 123 |
| 3 | Brown | 51 x 49 | 48 | 125 x 123 | 126 x 124 |
| 4 | White | 49 | 50 x 49 | 123 | 124 x 122 |
| 5 | Slate | 52 x 54 | 52 | 126 | 125 |
| 6 | Green | 53 x 52 | 51 x 51 | 123 x 123 | 124 x 123 |

* Start of pull, bottom spool.
** End of pull, top of spool.

Table A-2. Cable Results, Cable 1 and Cable 2.

| Fiber id | | Attenuation (dB/km) Before | Attenuation (dB/km) After | Attenuation (dB/km) Δ | Dispersion (ns/km) Before | Dispersion (ns/km) After | Dispersion (ns/km) Δ |
|---|---|---|---|---|---|---|---|
| **Cable 1: 071781-4C-1** | | | | | | | |
| 1 | Blue | 3.65 | 3.09 | -0.56 | 0.36 | 0.37 | +0.01 |
| 2 | Orange | 3.65 | 3.25 | -0.40 | 0.36 | 0.51 | +0.15 |
| 3 | Brown | 3.14 | 3.07 | -0.07 | 0.93 | 1.09 | +0.16 |
| 4 | White | 2.94 | 2.55 | -0.39 | 0.52 | 1.52 | +1.00 |
| 5 | Slate | 3.43 | 3.15 | -0.28 | 0.76 | 1.35 | +0.59 |
| 6 | Green | 3.42 | 3.30 | -0.12 | 0.33 | 0.52 | +0.19 |
| | Average | 3.37 | 3.06 | -0.30 | 0.54 | 0.89 | +0.35 |
| **Cable 2: 071881-4C-1** | | | | | | | |
| 1 | Blue | 3.47 | 4.22 | +0.73 | 1.03 | 0.94 | -0.09 |
| 2 | Orange | 3.52 | 3.68 | +0.16 | 0.72 | 0.77 | +0.05 |
| 3 | Brown | 2.94 | 3.04 | +0.10 | 0.52 | 0.72 | +0.20 |
| 4 | White | 2.94 | 3.32 | +0.38 | 0.52 | 0.84 | +0.32 |
| 5 | Slate | 3.12 | 3.87 | +0.75 | 1.34 | 1.39 | +0.05 |
| 6 | Green | 3.31 | 2.84 | -0.47 | 0.97 | 0.48 | -0.49 |
| | Average | 3.21 | 3.49 | +0.28 | 0.85 | 0.87 | +0.02 |

Table A-3. Cable Results, Cable 3 and Cable 4.

| Fiber id | | Attenuation (dB/km) Before | Attenuation (dB/km) After | Attenuation (dB/km) Δ | Dispersion (ns/km) Before | Dispersion (ns/km) After | Dispersion (ns/km) Δ |
|---|---|---|---|---|---|---|---|
| **Cable 3: 071881-4C-2** | | | | | | | |
| 1 | Blue | 3.29 | 3.23 | -0.06 | 0.44 | 0.55 | +0.11 |
| 2 | Orange | 3.15 | 3.40 | +0.25 | 0.31 | 0.52 | +0.21 |
| 3 | Brown | 3.34 | 3.15 | -0.19 | 0.68 | 0.55 | -0.13 |
| 4 | White | 3.20 | 3.56 | +0.36 | 0.60 | 0.50 | -0.10 |
| 5 | Slate | 3.23 | 4.11 | +0.88 | 0.34 | 0.67 | +0.33 |
| 6 | Green | 3.47 | 3.93 | +0.46 | 1.03 | 1.20 | +0.17 |
| | Average | 3.28 | 3.56 | +0.28 | 0.56 | 0.66 | +0.10 |
| **Cable 4: 071881-4C-3** | | | | | | | |
| 1 | Blue | 3.46 | 3.52 | +0.06 | 0.88 | 1.09 | +0.21 |
| 2 | Orange | 3.65 | 3.74 | +0.09 | 0.27 | 0.35 | +0.08 |
| 3 | Brown | 3.08 | 3.13 | +0.05 | 0.75 | 0.62 | -0.13 |
| 4 | White | 3.40 | 3.40 | 0.00 | 0.55 | 1.22 | +0.67 |
| 5 | Slate | 3.42 | 3.44 | +0.02 | 0.33 | 0.56 | +0.23 |
| 6 | Green | 3.07 | 3.31 | +0.24 | 0.64 | 0.56 | -0.08 |
| | Average | 3.35 | 3.42 | +0.07 | 0.57 | 0.73 | +0.16 |

Table A-4. Cable Results, Cable 5 and Cable 6.

| Fiber id | | Attenuation (dB/km) Before | After | Δ | Dispersion (ns/km) Before | After | Δ |
|---|---|---|---|---|---|---|---|
| **Cable 5: 072081-4C-1** | | | | | | | |
| 1 | Blue | 4.67 | 4.53 | -0.14 | 0.92 | 0.76 | -0.16 |
| 2 | Orange | 3.19 | 3.50 | +0.31 | 1.05 | 1.37 | +0.32 |
| 3 | Brown | 3.34 | 3.38 | +0.04 | 0.82 | 1.46 | +0.64 |
| 4 | White | 3.23 | 3.66 | +0.43 | 0.48 | 0.98 | +0.50 |
| 5 | Slate | 3.65 | 3.63 | -0.02 | 1.09 | 1.61 | +0.52 |
| 6 | Green | 3.21 | 3.43 | +0.22 | 0.83 | 0.68 | -0.15 |
| | Average | 3.55 | 3.69 | +0.14 | 0.87 | 1.14 | +0.27 |
| **Cable 6: 071681-4C-1** | | | | | | | |
| 1 | Blue | 3.30 | 3.21 | -0.09 | 0.32 | 0.32 | 0.00 |
| 2 | Orange | 3.14 | 3.14 | 0.00 | 0.72 | 0.72 | 0.00 |
| 3 | Brown | 3.15 | 3.08 | -0.07 | 0.31 | 0.51 | +0.20 |
| 4 | White | 3.08 | 2.82 | -0.18 | 0.75 | 0.21 | -0.54 |
| 5 | Slate | 3.20 | 2.94 | -0.26 | 0.64 | 0.69 | +0.05 |
| 6 | Green | 3.82 | 4.07 | +0.25 | 0.63 | 0.65 | +0.02 |
| | Average | 3.28 | 3.21 | -0.07 | 0.56 | 0.52 | -0.04 |

Table A-5. Cable Results, Cable 7 and Cable 8.

| | Attenuation (dB/km) | | | Dispersion (ns/km) | | |
|---|---|---|---|---|---|---|
| Fiber id | Before | After | Δ | Before | After | Δ |
| **Cable 7: 072081-4C-2** | | | | | | |
| 1 Blue | 3.30 | 3.42 | +0.12 | 0.77 | 1.00 | +0.23 |
| 2 Orange | 3.25 | 3.40 | +0.15 | 0.82 | 1.22 | +0.40 |
| 3 Brown | 3.85 | 4.18 | +0.33 | 0.25 | 0.37 | +0.12 |
| 4 White | 3.11 | 3.34 | +0.23 | 0.89 | 0.87 | +0.02 |
| 5 Slate | 3.91 | 4.11 | +0.20 | 0.39 | 0.69 | +0.30 |
| 6 Green | 4.00 | 3.73 | -0.27 | 0.47 | 0.57 | +0.10 |
| Average | 3.57 | 3.69 | +0.12 | 0.60 | 0.79 | +0.19 |
| **Cable 8: 082781-4C-1** | | | | | | |
| 1 Blue | 3.48 | 3.31 | -0.17 | 1.03 | 1.45 | +0.42 |
| 2 Orange | 2.87 | 2.95 | +0.08 | 0.81 | 0.81 | 0.00 |
| 3 Brown | 3.13 | 3.29 | +0.16 | 0.95 | 0.62 | -0.33 |
| 4 White | 2.62 | 3.62 | +1.00 | 0.98 | 1.41 | +0.43 |
| 5 Slate | 3.99 | 3.94 | -0.05 | 0.70 | 1.16 | +0.46 |
| 6 Green | 3.89 | 3.87 | -0.02 | 0.64 | 0.66 | +0.02 |
| Average | 3.33 | 3.50 | +0.17 | 0.85 | 1.01 | +0.16 |

Table A-6. Cable Results, Cable 10 and Cable 12.

| Fiber id | Attenuation (dB/km) Before | Attenuation (dB/km) After | Attenuation (dB/km) Δ | Dispersion (ns/km) Before | Dispersion (ns/km) After | Dispersion (ns/km) Δ |
|---|---|---|---|---|---|---|
| **Cable 10: 09181-4C-2** | | | | | | |
| 1 Blue | 3.39 | 3.64 | +0.25 | 1.17 | 1.05 | -0.12 |
| 2 Orange | 3.68 | 3.34 | -0.34 | 1.39 | 1.00 | -0.39 |
| 3 Brown | 2.52 | 4.30 | +1.78 | 1.55 | 0.43 | -1.12 |
| 4 White | 3.48 | 2.96 | -0.52 | 1.37 | 1.04 | -0.33 |
| 5 Slate | 3.39 | 4.01 | +0.61 | 1.57 | 0.52 | -1.05 |
| 6 Green | 4.26 | 3.67 | -0.59 | 1.29 | 1.49 | +0.20 |
| Average | 3.45 | 3.65 | +0.20 | 1.39 | 0.92 | -0.47 |
| **Cable 12: 091781-4C-1** | | | | | | |
| 1 Blue | 2.97 | 4.19 | +1.22 | 0.46 | 0.70 | +0.23 |
| 2 Orange | 3.06 | 3.03 | -0.03 | 0.66 | 1.20 | +0.54 |
| 3 Brown | 3.23 | 3.00 | -0.23 | 0.73 | 0.72 | -0.01 |
| 4 White | 3.48 | 3.37 | -0.11 | 0.81 | 0.70 | -0.11 |
| 5 Slate | 3.34 | 3.70 | +0.36 | 0.80 | 1.18 | +0.38 |
| 6 Green | 3.24 | 3.03 | -0.21 | 0.95 | 0.71 | -0.24 |
| Average | 3.22 | 3.38 | +0.16 | 0.73 | 0.86 | +0.13 |

Table A-7. Attenuation Versus Wavelength After Cabling (dB/km).*

| Fiber Identification | | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| **Cable 1: 071781-4C-1** | | | | | | | |
| 1 | Blue | 3.63 | 3.09 | 1.3 | 1.2 | 1.05 | 1.87 |
| 2 | Orange | 3.74 | 3.25 | 1.65 | 1.25 | 1.12 | 1.51 |
| 3 | Brown | 3.60 | 3.07 | 1.41 | 1.24 | 1.09 | 1.30 |
| 4 | White | 4.05 | 2.55 | 1.68 | 1.61 | 1.42 | 1.66 |
| 5 | Slate | 3.53 | 3.15 | 1.38 | 1.32 | 1.12 | 1.54 |
| 6 | Green | 4.82 | 3.30 | 3.17 | 2.43 | 2.13 | 1.58 |
| **Cable 2: 071881-4C-1** | | | | | | | |
| 1 | Blue | 4.75 | 4.22 | 2.33 | 2.05 | 1.73 | 2.17 |
| 2 | Orange | 4.24 | 3.68 | 2.05 | 1.90 | 1.60 | 1.37 |
| 3 | Brown | 3.41 | 3.04 | 1.53 | 1.33 | 1.11 | 1.46 |
| 4 | White | 3.81 | 3.32 | 1.57 | 1.47 | 1.13 | 2.10 |
| 5 | Slate | 4.15 | 3.87 | 2.02 | 1.82 | 1.67 | 1.23 |
| 6 | Green | 3.39 | 2.84 | 1.09 | 0.96 | 0.8 | 1.28 |

*Injected NA 0.089.

Table A-7. Attenuation Versus Wavelength After Cabling (dB/km) (continued).*

Cabie 3: 071881-4C-2

| Fiber Identification | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 3.86 | 3.23 | 1.50 | 1.34 | 1.14 | 1.42 |
| 2 Orange | 3.94 | 3.40 | 1.68 | 1.50 | 1.59 | 3.03 |
| 3 Brown | 3.55 | 3.15 | 1.78 | 1.32 | 1.21 | 0.75 |
| 4 White | 4.02 | 3.56 | 1.59 | 1.50 | 1.24 | 1.23 |
| 5 Slate | 4.46 | 4.11 | 2.39 | 2.03 | 1.77 | 0.66 |
| 6 Green | 4.27 | 3.93 | 1.87 | 1.47 | 1.11 | 1.41 |

Cable 4: 071881-4C-3

| Fiber Identification | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 4.08 | 3.52 | 1.56 | 1.51 | 1.19 | 1.19 |
| 2 Orange | 4.19 | 3.74 | 1.85 | 1.72 | 1.50 | 1.36 |
| 3 Brown | 3.69 | 3.13 | 1.20 | 1.11 | 0.90 | 1.01 |
| 4 White | 3.95 | 3.40 | 1.65 | 1.53 | 1.30 | 1.25 |
| 5 Slate | 3.94 | 3.44 | 1.73 | 1.65 | 1.37 | 1.24 |
| 6 Green | 3.83 | 3.31 | 1.60 | 1.45 | 1.22 | 0.89 |

*Injected NA 0.089.

Table A-7. Attenuation Versus Wavelength After Cabling (dB/km) (continued).*

Cable 5: 072081-4C-1

| Fiber Identification | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 5.02 | 4.53 | 2.67 | 2.58 | 2.36 | 2.65 |
| 2 Orange | 3.73 | 3.50 | 1.14 | 0.93 | 0.68 | 0.42 |
| 3 Brown | 3.91 | 3.38 | 1.58 | 1.43 | 1.25 | 1.15 |
| 4 White | 4.12 | 3.66 | 1.73 | 1.61 | 1.17 | 1.26 |
| 5 Slate | 4.31 | 3.63 | 1.39 | 1.14 | 0.78 | 0.57 |
| 6 Green | 3.92 | 3.46 | 1.59 | 5.0 | 1.21 | 1.10 |

Cable 6: 071681-4C-1

| Fiber Identification | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 3.71 | 3.21 | 1.42 | 1.26 | 1.05 | 1.32 |
| 2 Orange | 3.85 | 3.45 | 1.72 | 1.62 | 1.32 | 1.54 |
| 3 Brown | 3.49 | 3.08 | 1.36 | 1.22 | 1.22 | 3.46 |
| 4 White | 3.28 | 2.82 | 1.27 | 1.13 | 0.91 | 1.42 |
| 5 Slate | 3.34 | 2.94 | 1.30 | 1.35 | 1.16 | 1.97 |
| 6 Green | 4.63 | 4.02 | 1.86 | 1.80 | 1.01 | 1.82 |

*Injected NA 0.089.

Table A-7. Attenuation Versus Wavelength After Cabling (dB/km) (continued).*

Cable 7: 072081-4C-2

| Fiber Identification | | Wavelength (nm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
| 1 | Blue | 3.99 | 3.42 | 1.57 | 1.42 | 1.11 | 2.62 |
| 2 | Orange | 4.11 | 3.40 | 1.62 | 1.45 | 1.25 | 0.77 |
| 3 | Brown | 4.77 | 4.18 | 2.17 | 2.05 | 1.71 | 1.37 |
| 4 | White | 4.03 | 3.34 | 1.55 | 1.38 | 1.16 | 1.36 |
| 5 | Slate | 4.56 | 4.11 | 1.95 | 1.82 | 1.50 | 1.37 |
| 6 | Green | 4.32 | 3.73 | 2.03 | 1.93 | 1.65 | 1.28 |

Cable 8: 082781-4C-1

| Fiber Identification | | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 3.79 | 3.31 | 1.55 | 1.45 | 1.42 | 3.19 |
| 2 | Orange | 3.39 | 2.95 | 1.25 | 1.12 | 0.84 | 0.90 |
| 3 | Brown | 3.84 | 3.29 | 1.43 | 1.31 | 1.03 | 1.04 |
| 4 | White | 4.15 | 3.62 | 1.92 | 1.78 | 1.44 | 1.32 |
| 5 | Slate | 4.46 | 3.94 | 1.88 | 1.66 | 1.41 | 1.51 |
| 6 | Green | 4.43 | 3.87 | 2.16 | 2.00 | 1.72 | 1.63 |

*Injected NA 0.089.

Table A-7. Attenuation Versus Wavelength After Cabling (dB/km) (continued).*

Cable 10: 001881-4C-2

| Fiber Identification | | Wavelength (nm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
| 1 | Blue | 4.27 | 3.64 | 2.12 | 2.01 | 2.06 | 2.51 |
| 2 | Orange | 3.87 | 3.34 | 1.73 | 1.61 | 1.34 | 1.27 |
| 3 | Brown | 4.81 | 4.30 | 2.42 | 2.25 | 2.05 | 2.05 |
| 4 | White | 3.40 | 2.96 | 1.21 | 1.30 | 1.14 | 1.31 |
| 5 | Slate | 4.37 | 4.01 | 2.64 | 2.48 | 2.27 | 2.28 |
| 6 | Green | 4.20 | 3.67 | 1.79 | 1.58 | 1.30 | 1.05 |

Cable 12: 091781-4C-1A

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 4.62 | 4.19 | 2.34 | 2.19 | 1.86 | 1.99 |
| 2 | Orange | 3.47 | 3.03 | 1.58 | 1.46 | 1.27 | 1.26 |
| 3 | Brown | 3.45 | 3.00 | 1.50 | 1.39 | 1.20 | 1.30 |
| 4 | White | 3.92 | 3.37 | 1.70 | 1.55 | 1.29 | 1.37 |
| 5 | Slate | 4.09 | 3.70 | 2.16 | 2.05 | 1.87 | 1.99 |
| 6 | Green | 3.28 | 3.03 | 1.42 | 1.26 | 1.05 | 0.97 |

*Injected NA 0.089.

Table A-8. Attenuation Versus Wavelength After Cabling (dB/km).*

Cable 1: 071781-4C-1

| Fiber Identification | | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 3.63 | 3.09 | 1.3 | 1.2 | 1.05 | 1.87 |
| 2 | Orange | 3.74 | 3.25 | 1.65 | 1.25 | 1.12 | 1.51 |
| 3 | Brown | 3.60 | 3.07 | 1.41 | 1.24 | 1.09 | 1.30 |
| 4 | White | 4.05 | 2.55 | 1.68 | 1.61 | 1.42 | 1.66 |
| 5 | Slate | 3.53 | 3.15 | 1.38 | 1.32 | 1.12 | 1.54 |
| 6 | Green | 4.82 | 3.30 | 3.17 | 2.43 | 2.13 | 1.58 |

Cable 2: 071881-4C-1

| Fiber Identification | | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 4.75 | 4.22 | 2.33 | 2.05 | 1.73 | 2.17 |
| 2 | Orange | 4.24 | 3.68 | 2.05 | 1.90 | 1.60 | 1.37 |
| 3 | Brown | 3.41 | 3.04 | 1.53 | 1.33 | 1.11 | 1.46 |
| 4 | White | 3.81 | 3.32 | 1.57 | 1.47 | 1.13 | 2.10 |
| 5 | Slate | 4.15 | 3.87 | 2.02 | 1.82 | 1.67 | 1.23 |
| 6 | Green | 3.39 | 2.84 | 1.09 | 0.96 | 0.8 | 1.28 |

*Injected NA 0.089.

Table A-8. Attenuation Versus Wavelength After Cabling (dB/km) (continued).*

Cable 3: 071881-4C-2

| Fiber Identification | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 3.86 | 3.23 | 1.50 | 1.34 | 1.14 | 1.42 |
| 2 Orange | 3.94 | 3.40 | 1.68 | 1.50 | 1.59 | 3.03 |
| 3 Brown | 3.55 | 3.15 | 1.78 | 1.32 | 1.21 | 0.75 |
| 4 White | 4.02 | 3.56 | 1.59 | 1.50 | 1.24 | 1.23 |
| 5 Slate | 4.46 | 4.11 | 2.39 | 2.03 | 1.77 | 0.66 |
| 6 Green | 4.27 | 3.93 | 1.87 | 1.47 | 1.11 | 1.41 |

Cable 4: 071881-4C-3

| Fiber Identification | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 4.08 | 3.52 | 1.56 | 1.51 | 1.19 | 1.19 |
| 2 Orange | 4.19 | 3.74 | 1.85 | 1.72 | 1.50 | 1.36 |
| 3 Brown | 3.69 | 3.13 | 1.20 | 1.11 | 0.90 | 1.01 |
| 4 White | 3.95 | 3.40 | 1.65 | 1.53 | 1.30 | 1.25 |
| 5 Slate | 3.94 | 3.44 | 1.73 | 1.65 | 1.37 | 1.24 |
| 6 Green | 3.83 | 3.31 | 1.60 | 1.45 | 1.22 | 0.89 |

*Injected NA 0.089.

Table A-8. Attenuation Versus Wavelength After Cabling (dB/km) (continued).*

| Fiber Identification | | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| **Cable 5: 072081-4C-1** | | | | | | | |
| 1 | Blue | 5.02 | 4.53 | 2.67 | 2.58 | 2.36 | 2.65 |
| 2 | Orange | 3.73 | 3.50 | 1.14 | 0.93 | 0.68 | 0.42 |
| 3 | Brown | 3.91 | 3.38 | 1.58 | 1.43 | 1.25 | 1.15 |
| 4 | White | 4.12 | 3.66 | 1.73 | 1.61 | 1.17 | 1.26 |
| 5 | Slate | 4.31 | 3.63 | 1.39 | 1.14 | 0.78 | 0.57 |
| 6 | Green | 3.92 | 3.46 | 1.59 | 5.0 | 1.21 | 1.10 |
| **Cable 6: 071681-4C-1** | | | | | | | |
| 1 | Blue | 3.71 | 3.21 | 1.42 | 1.26 | 1.05 | 1.32 |
| 2 | Orange | 3.85 | 3.45 | 1.72 | 1.62 | 1.32 | 1.54 |
| 3 | Brown | 3.49 | 3.08 | 1.36 | 1.22 | 1.22 | 3.46 |
| 4 | White | 3.28 | 2.82 | 1.27 | 1.13 | 0.91 | 1.42 |
| 5 | Slate | 3.34 | 2.94 | 1.30 | 1.35 | 1.16 | 1.97 |
| 6 | Green | 4.63 | 4.02 | 1.86 | 1.80 | 1.01 | 1.82 |

*Injected NA 0.089.

Table A-8. Attenuation Versus Wavelength After Cabling (dB/km) (continued).*

| Fiber Identification | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| **Cable 7: 072081-4C-2** | | | | | | |
| 1 Blue | 3.99 | 3.42 | 1.57 | 1.42 | 1.11 | 2.62 |
| 2 Orange | 4.11 | 3.40 | 1.62 | 1.45 | 1.25 | 0.77 |
| 3 Brown | 4.77 | 4.18 | 2.17 | 2.05 | 1.71 | 1.37 |
| 4 White | 4.03 | 3.34 | 1.55 | 1.38 | 1.16 | 1.36 |
| 5 Slate | 4.56 | 4.11 | 1.95 | 1.82 | 1.50 | 1.37 |
| 6 Green | 4.32 | 3.73 | 2.03 | 1.93 | 1.65 | 1.28 |
| **Cable 8: 082781-4C-1** | | | | | | |
| 1 Blue | 3.79 | 3.31 | 1.55 | 1.45 | 1.42 | 3.19 |
| 2 Orange | 3.39 | 2.95 | 1.25 | 1.12 | 0.84 | 0.90 |
| 3 Brown | 3.84 | 3.29 | 1.43 | 1.31 | 1.03 | 1.04 |
| 4 White | 4.15 | 3.62 | 1.92 | 1.78 | 1.44 | 1.32 |
| 5 Slate | 4.46 | 3.94 | 1.88 | 1.66 | 1.41 | 1.51 |
| 6 Green | 4.43 | 3.87 | 2.16 | 2.00 | 1.72 | 1.63 |

*Injected NA 0.089.

Table A-8. Attenuation Versus Wavelength After Cabling (dB/km) (continued).*

Cable 10: 001881-4C-2

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 4.27 | 3.64 | 2.12 | 2.01 | 2.06 | 2.51 |
| 2 | Orange | 3.87 | 3.34 | 1.73 | 1.61 | 1.34 | 1.27 |
| 3 | Brown | 4.81 | 4.30 | 2.42 | 2.25 | 2.05 | 2.05 |
| 4 | White | 3.40 | 2.96 | 1.21 | 1.30 | 1.14 | 1.31 |
| 5 | Slate | 4.37 | 4.01 | 2.64 | 2.48 | 2.27 | 2.28 |
| 6 | Green | 4.20 | 3.67 | 1.79 | 1.58 | 1.30 | 1.05 |

*Injected NA 0.089.

Table A-8. Attenuation Versus Wavelength After Cabling (dB/km) (continued).*

Cable 12: 091781-4C-1A

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 4.62 | 4.19 | 2.34 | 2.19 | 1.86 | 1.99 |
| 2 | Orange | 3.47 | 3.03 | 1.58 | 1.46 | 1.27 | 1.26 |
| 3 | Brown | 3.45 | 3.00 | 1.50 | 1.39 | 1.20 | 1.30 |
| 4 | White | 3.92 | 3.37 | 1.70 | 1.55 | 1.29 | 1.37 |
| 5 | Slate | 4.09 | 3.70 | 2.16 | 2.05 | 1.87 | 1.99 |
| 6 | Green | 3.28 | 3.03 | 1.42 | 1.26 | 1.05 | 0.97 |

*Injected NA 0.089.

# APPENDIX B

# FUNGUS TESTING RESULTS

AEROSPACE RESEARCH CORPORATION
TEST DATA

CUSTOMER ITT Electro-Optical Division TEST ITEM Fiber Optic Cable

TEST SPECIFICATION MIL-STD-810B, Method 508.1, Procedure I

PARAGRAPH NUMBER ______ PART NUMBER ______

SERIAL NUMBER 2, 5, 7 and TAOC

TEST TITLE Fungus Test

P.O. NUMBER 34395 TEST CONDUCTED BY Gary W. Long

DATE 8-11-81 TEST TEMP. +84 °F ROOM TEMP. +72 °F BAROMETRIC PRESSURE 29.04 In. Hg.

Prior to start of Fungus Test the Optic Fiber samples were cleaned with isopropyl alcohol. The samples were then placed in the Fungus Chamber and sprayed with previously prepared and tested fungus culture. The fungus culture preparation and test were conducted in accordance with MIL-STD-810B, Method 508.1, Procedure 1.

The chamber was maintained at +84°F and 95 percent relative humidity for a period of 28 days. The test was started on August 11, 1981, and was completed on September 8, 1981.

At the end of the 28 day test the samples were visually inspected for fungus growth.

A light fungus growth was observed on all samples.

The Optic Fiber samples were returned to ITT, Electro-Optical Products Division for a complete inspection and test evaluation.

CERTIFICATION

We certify that this test data is a true report on our Fungus Test on four Optic Fiber samples, S/N's 2, 5, 7 and TAOC, submitted by ITT, Electro-Optical Products Division of Roanoke, Virginia. Calibration of our instrumentation is traceable to the National Bureau of Standards.

Respectfully submitted,

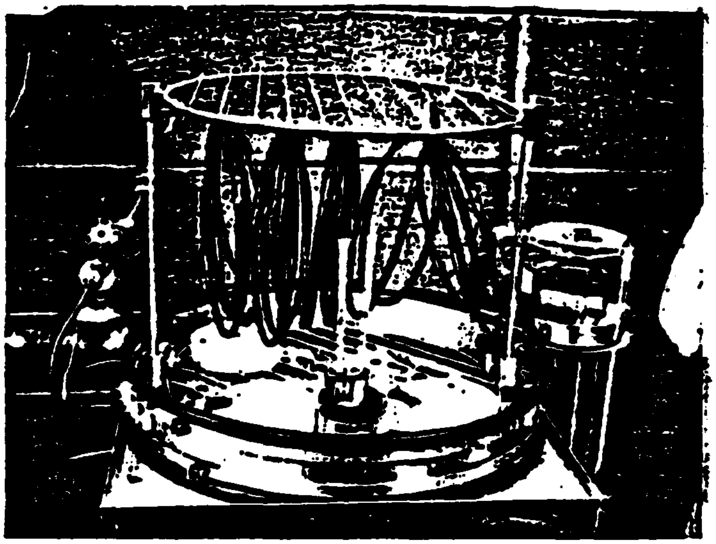
AEROSPACE RESEARCH CORPORATION

Leslie C. Rose

Leslie C. Rose
Vice President

Subscribed and sworn to before me this 9th day of September, 1981.

Betty C. Fitzpatrick My commission expires July 16, 1984.
Notary Public



# APPENDIX C

## HUMIDITY TEST DATA

Table C-1. Humidity Test Cable Results, Cable 2 and Cable 4.

| Fiber id | | Attenuation (dB/km) Before | Attenuation (dB/km) After | Attenuation (dB/km) Δ | Dispersion (ns/km) Before | Dispersion (ns/km) After | Dispersion (ns/km) Δ |
|---|---|---|---|---|---|---|---|
| **Cable 2: 071881-4C-1** | | | | | | | |
| 1 | Blue | 3.98 | 3.70 | -0.28 | 1.61 | 0.96 | -0.65 |
| 2 | Orange | 3.58 | 3.30 | -0.28 | 0.75 | 0.77 | +0.02 |
| 3 | Brown | 3.30 | 3.33 | +0.03 | 0.62 | 0.69 | +0.07 |
| 4 | White | 3.09 | 3.16 | +0.07 | 0.74 | 0.94 | +0.20 |
| 5 | Slate | 3.33 | 2.12 | -1.21 | 0.89 | 1.24 | +0.35 |
| 6 | Green | 3.54 | 3.08 | -0.46 | 0.52 | 0.50 | -0.02 |
| | Average | 3.47 | 3.11 | -0.36 | 0.85 | 0.85 | 0.00 |
| **Cable 4: 071881-4C-3** | | | | | | | |
| 1 | Blue | 3.63 | 3.06 | -0.57 | 1.28 | 1.24 | -0.04 |
| 2 | Orange | 3.73 | 3.79 | +0.06 | 0.40 | 0.34 | -0.06 |
| 3 | Brown | 3.24 | 3.34 | +0.10 | 0.73 | 0.68 | -0.05 |
| 4 | White | 3.36 | 3.37 | +0.01 | 1.32 | 1.37 | +0.05 |
| 5 | Slate | 3.42 | 3.36 | -0.06 | 0.54 | 0.56 | +0.02 |
| 6 | Green | 3.45 | 3.92 | +0.47 | 0.56 | 0.64 | +0.08 |
| | Average | 3.47 | 3.47 | 0.00 | 0.80 | 0.80 | 0.00 |

Table C-2. Humidity Test Cable Results, Cable 6 and Cable 7.

| Fiber id | | Attenuation (dB/km) Before | After | Δ | Dispersion (ns/km) Before | After | Δ |
|---|---|---|---|---|---|---|---|
| | | **Cable 6: 071681-4C-1** | | | | | |
| 1 | Blue | 3.50 | 3.35 | -0.15 | 0.69 | 0.80 | +0.11 |
| 2 | Orange | 3.30 | 3.49 | +0.19 | 0.63 | 0.71 | +0.08 |
| 3 | Brown | 3.57 | 3.57 | 0.00 | 0.49 | 0.56 | +0.07 |
| 4 | White | 3.21 | 3.52 | +0.31 | 0.59 | 0.65 | +0.06 |
| 5 | Slate | 3.21 | 3.39 | +0.18 | 0.69 | 0.75 | +0.06 |
| 6 | Green | 3.87 | 3.98 | +0.11 | 0.55 | 0.78 | +0.23 |
| | Average | 3.44 | 3.55 | +0.11 | 0.61 | 0.71 | +0.10 |
| | | **Cable 7: 072081-4C-2** | | | | | |
| 1 | Blue | 3.46 | 3.22 | -0.24 | 0.97 | 0.87 | -0.10 |
| 2 | Orange | 3.49 | 3.43 | -0.06 | 1.48 | 1.02 | -0.46 |
| 3 | Brown | 4.20 | 3.50 | -0.70 | 0.43 | 0.34 | -0.09 |
| 4 | White | 3.67 | 3.31 | -0.36 | 1.21 | 1.09 | -0.12 |
| 5 | Slate | 4.40 | 4.33 | -0.07 | 0.64 | 0.58 | -0.06 |
| 6 | Green | 3.57 | 4.21 | +0.64 | 0.61 | 0.49 | -0.12 |
| | Average | 3.80 | 3.67 | -0.13 | 0.89 | 0.73 | -0.16 |

Table C-3. Attenuation Versus Wavelength* (dB/km) After Humidity.

| Fiber Identification | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| **Cable 2: 071881-4C-1** | | | | | | |
| 1 Blue | 4.16 | 3.70 | 1.71 | 1.51 | 1.17 | 1.05 |
| 2 Orange | 3.80 | 3.30 | 1.51 | 1.36 | 1.16 | 1.33 |
| 3 Brown | 3.77 | 3.33 | 1.73 | 1.61 | 1.38 | 1.42 |
| 4 White | 3.75 | 3.16 | 1.52 | 1.47 | 1.20 | 1.20 |
| 5 Slate | 3.75 | 2.12 | 1.42 | 1.18 | 1.10 | 1.19 |
| 6 Green | 3.49 | 3.08 | 1.46 | 1.30 | 1.11 | 1.13 |
| **Cable 4: 071881-4C-3** | | | | | | |
| 1 Blue | 3.49 | 3.06 | 1.37 | 1.35 | 1.20 | 1.36 |
| 2 Orange | 4.31 | 3.79 | 1.92 | 1.77 | 1.53 | 1.56 |
| 3 Brown | 3.81 | 3.34 | 1.57 | 1.34 | 1.07 | 1.06 |
| 4 White | 3.87 | 3.37 | 1.70 | 1.59 | 1.47 | 1.50 |
| 5 Slate | 3.76 | 3.36 | 1.66 | 1.56 | 1.29 | 1.30 |
| 6 Green | 4.46 | 3.92 | 2.20 | 2.04 | 1.80 | 1.81 |

*Injected NA 0.089.

Table C-3. Attenuation Versus Wavelength* (dB/km) After Humidity (continued).

| Fiber Identification | | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| **Cable 6: 071681-4C-1** | | | | | | | |
| 1 | Blue | 3.88 | 3.35 | 1.49 | 1.34 | 1.16 | 1.20 |
| 2 | Orange | 3.96 | 3.49 | 1.78 | 1.61 | 1.37 | 1.32 |
| 3 | Brown | 3.96 | 3.57 | 1.71 | 1.62 | 1.69 | 3.58 |
| 4 | White | 4.02 | 3.52 | 1.73 | 1.58 | 1.30 | 1.35 |
| 5 | Slate | 3.89 | 3.39 | 1.59 | 1.46 | 1.20 | 1.27 |
| 6 | Green | 4.66 | 3.98 | 1.87 | 1.65 | 1.37 | 1.22 |
| **Cable 7: 072081-4C-2** | | | | | | | |
| 1 | Blue | 3.72 | 3.22 | 1.55 | 1.38 | 1.14 | 1.12 |
| 2 | Orange | 3.93 | 3.43 | 1.62 | 1.46 | 0.62 | 0.59 |
| 3 | Brown | 3.96 | 3.50 | 1.66 | 1.63 | 1.52 | 1.75 |
| 4 | White | 3.90 | 3.31 | 1.41 | 1.47 | 1.15 | 1.55 |
| 5 | Slate | 4.88 | 4.33 | 2.20 | 1.99 | 1.72 | 1.71 |
| 6 | Green | 4.74 | 4.21 | 2.41 | 2.26 | 2.09 | 2.02 |

*Injected NA 0.089.

Table C-4. Attenuation Versus Injected NA After Humidity Test (Wavelength 820 nm).

Cable 2: 071881-4C-1

| Fiber Identification | | Injection NA 0.089 | 0.0124 | 0.0176 | 0.243 |
|---|---|---|---|---|---|
| 1 | Blue | 4.16 | 3.84 | 2.70 | 3.36 |
| 2 | Orange | 3.80 | 2.79 | 3.73 | 3.82 |
| 3 | Brown | 3.77 | 3.77 | 3.44 | 3.40 |
| 4 | White | 3.75 | 3.52 | 2.61 | 3.03 |
| 5 | Slate | 3.75 | 3.56 | 3.60 | 2.49 |
| 6 | Green | 3.49 | 3.32 | 2.61 | 2.42 |

Cable 4: 071881-4C-3

| Fiber Identification | | 0.089 | 0.0124 | 0.0176 | 0.243 |
|---|---|---|---|---|---|
| 1 | Blue | 3.49 | 3.51 | 3.57 | 3.57 |
| 2 | Orange | 4.31 | 4.36 | 4.23 | 4.30 |
| 3 | Brown | 3.81 | 3.99 | 4.06 | 4.08 |
| 4 | White | 3.87 | 3.65 | 3.25 | 3.27 |
| 5 | Slate | 3.76 | 3.75 | 4.04 | 4.13 |
| 6 | Green | 4.46 | 4.43 | 4.49 | 4.81 |

Table C-4. Attenuation Versus Injected NA After Humidity Test (Wavelength 820 nm) (continued).

Cable 6: 071681-4C-1

| Fiber Identification | Injection NA 0.089 | 0.0124 | 0.0176 | 0.243 |
|---|---|---|---|---|
| 1 Blue | 3.88 | 3.98 | 3.85 | 4.01 |
| 2 Orange | 3.96 | 3.97 | 4.08 | 4.26 |
| 3 Brown | 3.96 | 3.74 | 4.10 | 4.15 |
| 4 White | 4.02 | 4.01 | 4.30 | 4.29 |
| 5 Slate | 3.89 | 3.90 | 4.00 | 4.06 |
| 6 Green | 4.66 | 4.70 | 4.61 | 4.83 |

Cable 7: 072081-4C-2

| Fiber Identification | Injection NA 0.089 | 0.0124 | 0.0176 | 0.243 |
|---|---|---|---|---|
| 1 Blue | 3.72 | 3.92 | 4.00 | 4.23 |
| 2 Orange | 3.93 | 3.86 | 3.98 | 4.24 |
| 3 Brown | 3.96 | 3.84 | 3.43 | 4.09 |
| 4 White | 3.90 | 4.04 | 3.93 | 3.91 |
| 5 Slate | 4.88 | 4.80 | 4.86 | 4.87 |
| 6 Green | 4.74 | 4.92 | 5.02 | 5.03 |

Table C-5. Numerical Aperture (90% Power) After Temperature Cycling Test.

| Fiber Identification | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Blue | 0.19 | 0.22 | 0.18 | 0.22 | 0.20 | 0.21 | 0.22 | 0.20 | - | 0.19 | - | 0.20 |
| 2 | Orange | 0.19 | 0.21 | 0.19 | 0.20 | 0.19 | 0.23 | 0.20 | 0.21 | - | 0.20 | - | 0.19 |
| 3 | Brown | 0.18 | 0.22 | 0.21 | 0.21 | 0.23 | 0.20 | 0.22 | 0.20 | - | 0.18 | - | 0.18 |
| 4 | White | 0.21 | 0.25 | 0.19 | 0.20 | 0.19 | 0.22 | 0.22 | 0.22 | - | 0.21 | - | 0.19 |
| 5 | Slate | 0.20 | 0.27 | 0.20 | 0.23 | 0.20 | 0.21 | 0.23 | 0.20 | - | 0.18 | - | 0.20 |
| 6 | Green | 0.19 | 0.23 | 0.19 | 0.21 | 0.19 | 0.21 | 0.21 | 0.22 | - | 0.20 | - | 0.19 |

# APPENDIX D

# VIBRATION TEST DATA

Table D-1. Vibration Test Cable Results, Cable 2 and Cable 6.

| Fiber id | | Attenuation (dB/km) Before | Attenuation (dB/km) After | Attenuation (dB/km) Δ | Dispersion (ns/km) Before | Dispersion (ns/km) After | Dispersion (ns/km) Δ |
|---|---|---|---|---|---|---|---|
| **Cable 2: 071881-4C-1** | | | | | | | |
| 1 | Blue | 3.70 | 3.56 | -0.14 | 0.96 | 1.61 | +0.65 |
| 2 | Orange | 3.30 | 3.59 | +0.29 | 0.77 | 0.75 | -0.02 |
| 3 | Brown | 3.33 | 3.52 | +0.19 | 0.69 | 0.62 | -0.07 |
| 4 | White | 3.16 | 2.95 | -0.21 | 0.94 | 0.74 | -0.20 |
| 5 | Slate | 2.12 | 2.92 | +0.80 | 1.24 | 0.89 | -0.35 |
| 6 | Green | 3.08 | 3.17 | +0.09 | 0.50 | 0.52 | +0.02 |
| | Average | 3.11 | 3.28 | +0.17 | 0.85 | 0.85 | 0.00 |
| **Cable 6: 071681-4C-1** | | | | | | | |
| 1 | Blue | 3.35 | 2.27 | -1.08 | 0.80 | 0.80 | 0.00 |
| 2 | Orange | 3.49 | 3.78 | +0.29 | 0.71 | 0.82 | +0.11 |
| 3 | Brown | 3.57 | 3.40 | -0.17 | 0.56 | 0.50 | -0.06 |
| 4 | White | 3.52 | 2.26 | -1.26 | 0.65 | 0.62 | -0.03 |
| 5 | Slate | 3.39 | 3.12 | -0.26 | 0.75 | 0.66 | -0.09 |
| 6 | Green | 3.98 | 3.56 | -0.42 | 0.78 | 0.62 | -0.16 |
| | Average | 3.55 | 3.07 | -0.48 | 0.71 | 0.67 | -0.04 |

Table D-2. Vibration Test Cable Results, Cable 7 and Cable 8.

| Fiber id | | Attenuation (dB/km) Before | Attenuation (dB/km) After | Attenuation (dB/km) Δ | Dispersion (ns/km) Before | Dispersion (ns/km) After | Dispersion (ns/km) Δ |
|---|---|---|---|---|---|---|---|
| **Cable 7: 072081-4C-2** | | | | | | | |
| 1 | Blue | 3.22 | 3.50 | +0.28 | 0.87 | 0.89 | +0.02 |
| 2 | Orange | 3.43 | 2.92 | -0.51 | 1.02 | 1.22 | +0.20 |
| 3 | Brown | 3.50 | 4.46 | +0.96 | 0.34 | 0.36 | +0.02 |
| 4 | White | 3.31 | 3.03 | -0.28 | 1.09 | 1.05 | -0.04 |
| 5 | Slate | 4.33 | 4.12 | -0.21 | 0.58 | 0.59 | +0.01 |
| 6 | Green | 4.21 | 3.84 | -0.37 | 0.49 | 0.54 | +0.05 |
| | Average | 3.67 | 3.64 | -0.03 | 0.73 | 0.77 | +0.04 |
| **Cable 8: 082781-4C-1** | | | | | | | |
| 1 | Blue | 4.07 | 3.36 | -0.71 | 1.80 | 1.58 | -0.22 |
| 2 | Orange | 2.81 | 2.97 | +0.16 | 0.75 | 0.75 | 0.00 |
| 3 | Brown | 3.06 | 3.20 | +0.14 | 0.48 | 0.50 | +0.02 |
| 4 | White | 3.46 | 3.44 | -0.02 | 1.22 | 1.28 | +0.06 |
| 5 | Slate | 3.32 | 4.42 | +1.10 | 0.86 | 0.88 | +0.02 |
| 6 | Green | 3.62 | 4.24 | +0.62 | 0.74 | 0.75 | +0.01 |
| | Average | 3.40 | 3.61 | +0.21 | 0.97 | 0.95 | -0.02 |

Table D-3. Attenuation Versus Wavelength* (dB/km) After Vibration.

Cable 2

| Fiber Identification | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 4.14 | 3.56 | 1.58 | 1.40 | 1.12 | 1.01 |
| 2 Orange | 3.98 | 3.59 | 1.77 | 1.63 | 1.39 | 1.41 |
| 3 Brown | 3.52 | 3.08 | 1.50 | 1.34 | 1.15 | 1.18 |
| 4 White | 3.40 | 2.95 | 1.43 | 1.24 | 1.03 | 1.08 |
| 5 Slate | 3.42 | 2.92 | 1.10 | 1.14 | 1.02 | 1.31 |
| 6 Green | 3.49 | 3.17 | 1.44 | 1.37 | 1.02 | 1.09 |
| Cable 6: 071681-4C-1 | | | | | | |
| 1 Blue | 3.40 | 2.27 | 1.13 | 1.33 | 1.26 | 1.69 |
| 2 Orange | 3.89 | 3.78 | 1.94 | 1.64 | 1.39 | 1.35 |
| 3 Brown | 3.83 | 3.40 | 1.69 | 1.58 | 1.62 | 2.48 |
| 4 White | 2.96 | 2.26 | 1.26 | 1.00 | 0.73 | 0.80 |
| 5 Slate | 3.63 | 3.12 | 1.53 | 1.39 | 1.18 | 1.23 |
| 6 Green | 4.12 | 3.56 | 1.63 | 1.48 | 1.21 | 1.16 |

*Injected NA 0.089.

Table D-3. Attenuation Versus Wavelength* (dB/km) After Vibration (continued).

Cable 7: 072081-4C-2

| Fiber Identification | Wavelength (nm) 620 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 4.04 | 3.50 | 1.71 | 1.50 | 1.21 | 1.23 |
| 2 Orange | 3.07 | 2.92 | 1.63 | 1.67 | 1.69 | 1.87 |
| 3 Brown | 4.93 | 4.46 | 2.46 | 2.27 | 1.97 | 1.97 |
| 4 White | 3.50 | 3.03 | 1.32 | 1.23 | 1.02 | 1.33 |
| 5 Slate | 4.59 | 4.12 | 2.07 | 1.88 | 1.49 | 1.59 |
| 6 Green | 4.37 | 3.84 | 2.17 | 2.05 | 1.75 | 1.74 |

Cable 8: 082781-4C-1

| Fiber Identification | 620 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 3.92 | 3.36 | 1.62 | 1.45 | 1.44 | 3.17 |
| 2 Orange | 3.37 | 2.97 | 1.33 | 1.22 | 0.99 | 1.07 |
| 3 Brown | 3.57 | 3.20 | 1.45 | 1.28 | 1.07 | 1.22 |
| 4 White | 3.89 | 3.44 | 1.69 | 1.62 | 1.29 | 1.24 |
| 5 Slate | 4.50 | 4.42 | 2.04 | 1.78 | 1.38 | 1.27 |
| 6 Green | 4.74 | 4.24 | 2.48 | 2.38 | 2.17 | 2.07 |

*Injected NA 0.089.

Table D-4. Attenuation Versus Injected NA After Vibration (Wavelength 820 nm).

Cable 2: 071881-4C-1

| Fiber Identification | Injection NA 0.089 | 0.0124 | 0.0176 | 0.243 |
|---|---|---|---|---|
| 1 Blue | 4.14 | 4.16 | 4.22 | 4.36 |
| 2 Orange | 3.98 | 4.01 | 4.19 | 4.44 |
| 3 Brown | 3.52 | 3.67 | 3.69 | 3.65 |
| 4 White | 3.40 | 3.36 | 3.67 | 3.76 |
| 5 Slate | 3.42 | 3.50 | 3.63 | 3.80 |
| 6 Green | 3.61 | 3.48 | 3.58 | 3.71 |

Cable 6: 071681-4C-1

| Fiber Identification | 0.089 | 0.0124 | 0.0176 | 0.243 |
|---|---|---|---|---|
| 1 Blue | 3.40 | 3.40 | 3.54 | 3.65 |
| 2 Orange | 3.89 | 3.96 | 3.86 | 4.10 |
| 3 Brown | 3.83 | 3.89 | 4.01 | 4.07 |
| 4 White | 2.96 | 2.42 | 2.26 | 2.27 |
| 5 Slate | 3.63 | 3.63 | 3.64 | 3.93 |
| 6 Green | 4.12 | 3.97 | 4.01 | 4.18 |

Table D-4. Attenuation Versus Injected NA After Vibration (Wavelength 820 nm) (continued).

| Fiber Identification | Injection NA 0.089 | 0.0124 | 0.0176 | 0.243 |
|---|---|---|---|---|
| **Cable 7: 072081-4C-2** | | | | |
| 1 Blue | 4.04 | 4.14 | 4.46 | 4.48 |
| 2 Orange | 3.07 | 4.70 | 4.08 | 3.82 |
| 3 Brown | 4.93 | 4.95 | 4.88 | 5.27 |
| 4 White | 3.50 | 3.34 | 3.58 | 3.78 |
| 5 Slate | 4.59 | 4.28 | 4.31 | 4.45 |
| 6 Green | 4.37 | 4.55 | 4.61 | 4.72 |
| **Cable 8: 082781-4C-1** | | | | |
| 1 Blue | 3.92 | 3.69 | 3.90 | 3.89 |
| 2 Orange | 3.37 | 3.54 | 3.64 | 3.63 |
| 3 Brown | 3.57 | 3.61 | 3.85 | 3.91 |
| 4 White | 3.89 | 3.88 | 3.85 | 3.39 |
| 5 Slate | 4.50 | 4.57 | 3.91 | 3.77 |
| 6 Green | 4.74 | 4.67 | 4.97 | 5.04 |

Table D-5. Numerical Aperture (90% Power) After Vibration.

| Fiber Identification | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Blue | – | 0.18 | – | – | – | 0.19 | 0.18 | 0.19 | – | – | – | – |
| 2 Orange | – | 0.19 | – | – | – | 0.19 | 0.18 | 0.18 | – | – | – | – |
| 3 Brown | – | 0.19 | – | – | – | 0.19 | 0.20 | 0.19 | – | – | – | – |
| 4 White | – | 0.19 | – | – | – | 0.19 | 0.20 | 0.19 | – | – | – | – |
| 5 Slate | – | 0.19 | – | – | – | 0.20 | 0.19 | 0.18 | – | – | – | – |
| 6 Green | – | 0.18 | – | – | – | 0.19 | 0.19 | 0.23 | – | – | – | – |

# AEROSPACE RESEARCH CORPORATION
## TEST DATA

CUSTOMER ITT, Electro-Optical Products TEST ITEM Fiber Optic Cable (1 reel)

TEST SPECIFICATION Doc. Id. No. 80-29-09, Revision II

PARAGRAPH NUMBER 4.6 PART NUMBER

SERIAL NUMBER # 2

TEST TITLE Vibration Test (Loose Cargo)

P.O. NUMBER 34394-01 TEST CONDUCTED BY Gary W. Long

DATE 9-26-81 TEST TEMP. +70 °F ROOM TEMP. +70 °F BAROMETRIC PRESSURE 29.20 In. Hg.

The Loose Cargo Vibration Test was conducted in accordance with paragraph 4.6 of Preproduction Test Procedure for Ruggedized Tactical Fiber Optic Cable Document Identification number 80-29-09, Revision II.

The test sample was placed in the test fixture with reel axis perpendicular to test bed of package tester. The package tester operated at 284 r.p.m., with 1 inch vertical double displacement. The sample was vibrated for 30 minutes.

The reel was then turned 180 degrees and tested for 30 minutes.

The reel was then placed in the axis parallel to the test bed and tested for 30 minutes. After 30 minutes vibration the reel was turned 180 degrees and vibrated for 30 minutes.

At the conclusion of the 2 hour vibration test the sample was inspected for evidence of visible physical damage and none was observed.

Remarks: The reel of Fiber Optic Cable was returned to ITT for complete inspection and test evaluation.

4

# AEROSPACE RESEARCH CORPORATION
## TEST DATA

CUSTOMER ITT, Electro-Optical Products TEST ITEM Fiber Optic Cable (1 reel)

TEST SPECIFICATION Doc. Id No. 80-29-09, Revision II

PARAGRAPH NUMBER 4.6 PART NUMBER

SERIAL NUMBER # 2

TEST TITLE Vibration Test (Secured Cargo)

P.O. NUMBER 34395-01 TEST CONDUCTED BY S.D. Bernard

DATE 9-25-81 TEST TEMP. +78 °F ROOM TEMP. +78 °F BAROMETRIC PRESSURE 29.33 In. Hg.

The Secured Cargo Vibration Test was conducted in accordance with Preproduction Test Procedure for Ruggedized Tactical Fiber Optic Cable Document Identification number 80-29-09, Revision II.

The test sample was mounted on the vibration exciter and subjected to the following secured cargo vibration test in the lateral and longitudinal axes. The vibration time was 84 minutes per axis. The sweep time from 6 to 200 to 6 Hz was 12 minutes.

| Frequency, Hz | G level |
|---|---|
| 6 – 200 | 1.5 |

At the conclusion of the vibration test the sample was inspected for evidence of visible physical damage and none was observed.

4

CERTIFICATION

We certify that this test data is a true report of our Vibration Tests (Secured Cargo, and Loose Cargo) on one reel of Fiber Optic Cable, submitted by ITT, Electro-Optical Products Division, Roanoke, Virginia. Calibration of our instrumentation is traceable to the National Bureau of Standards.

Respectfully submitted,

AEROSPACE RESEARCH CORPORATION

Leslie C. Rose

Leslie C. Rose
Vice President

Subscribed and sworn to before me this 29th day of September, 1981.

Betty C. Fitzpatrick My commission expires July 16, 1984.
Notary Public

# AEROSPACE RESEARCH CORPORATION
## TEST DATA

CUSTOMER ITT, Electro-Optical Products TEST ITEM Fiber Optic Cable (1 reel)

TEST SPECIFICATION Doc. Id No. 80-29-09, Revision II

PARAGRAPH NUMBER 4.6 PART NUMBER

SERIAL NUMBER #6 and #7

TEST TITLE Vibration Test (Secured Cargo)

P.O. NUMBER 34395-01 TEST CONDUCTED BY Henry Messenger

DATE 9-21-81 TEST TEMP. +70 °F ROOM TEMP. +70 °F BAROMETRIC PRESSURE 29.03 In. Hg.

The Secured Cargo Vibration Test was conducted in accordance with Preproduction Test Procedure for Ruggedized Tactical Fiber Optic Cable Document Identification number 80-29-09. Revision II.

The test sample was mounted on the vibration exciter and subjected to the following secured cargo vibration test in the lateral and longitudinal axes. The vibration time was 84 minutes per axis. The sweep time from 6 to 200 to 6 Hz was 12 minutes.

| Frequency, Hz | G level |
|---|---|
| 5 - 200 | 1.5 |

At the conclusion of the vibration test the sample was inspected for evidence of visible physical damage and none was observed.

# AEROSPACE RESEARCH CORPORATION
## TEST DATA

CUSTOMER ITT, Electro-Optical Products TEST ITEM Fiber Optic Cable (1 reel)

TEST SPECIFICATION Doc. Id. No. 80-29-09, Revision II

PARAGRAPH NUMBER 4.6 PART NUMBER

SERIAL NUMBER #6 and #7

TEST TITLE Vibration Test (Loose Cargo)

P.O. NUMBER 34395-01 TEST CONDUCTED BY Gary W. Long

DATE 9-22-81 TEST TEMP. +70 °F ROOM TEMP. +70 °F BAROMETRIC PRESSURE 29.00 In. Hg.

The Loose Cargo Vibration Test was conducted in accordance with paragraph 4.6 of Preproduction Test Procedure for Ruggedized Tactical Fiber Optic Cable Document Identification number 80-29-09, Revision II.

The test sample was placed in the test fixture with reel axis perpendicular to test bed of package tester. The package tester operated at 284 r.p.m., with 1 inch vertical double displacement. The sample was vibrated for 30 minutes.

The reel was then turned 180 degrees and tested for 30 minutes.

The reel was then placed in the axis parallel to the test bed and tested for 30 minutes. After 30 minutes vibration the reel was turned 180 degrees and vibrated for 30 minutes.

At the conclusion of the 2 hour vibration test the sample was inspected for evidence of visible physical damage and none was observed.

Remarks: The reel of Fiber Optic Cable was returned to ITT for complete inspection and test evaluation.

4

CERTIFICATION

We certify that this test data is a true report of our Vibration Tests (Secured Cargo and Loose Cargo) on two reels of Fiber Optic Cable. S/N's 6 and 7, submitted by ITT, Electro-Optical Products Division, Roanoke, Va. Calibration of our instrumentation is traceable to the National Bureau of Standards.

Respectfully submitted,

AEROSPACE RESEARCH CORPORATION

Leslie C. Rose

Leslie C. Rose
Vice President

Subscribed and sworn to before me this 22nd day of September, 1981.

Betty C. Fitzpatrick
Notary Public

My commission expires July 16, 1984.

# AEROSPACE RESEARCH CORPORATION
## TEST DATA

CUSTOMER ITT, Electro-Optical Products TEST ITEM Fiber Optic Cable (1 reel)

TEST SPECIFICATION Doc. Id. No. 80-29-09, Revision II

PARAGRAPH NUMBER 4.6 PART NUMBER

SERIAL NUMBER #8

TEST TITLE Vibration Test (Loose Cargo)

P.O. NUMBER 34395 TEST CONDUCTED BY Gary W. Long

DATE 9-17-81 TEST TEMP. +75 °F ROOM TEMP. +75 °F BAROMETRIC PRESSURE 29.03 In. Hg.

The Loose Cargo Vibration Test was conducted in accordance with paragraph 4.6 of Preproduction Test Procedure for Ruggedized Tactical Fiber Optic Cable Document Identification number 80-29-09, Revision II.

The test sample was placed in the test fixture with reel axis perpendicular to test bed of package tester. The package tester operated at 284 r.p.m., with 1 inch vertical double displacement. The sample was vibrated for 30 minutes.

The reel was then turned 180 degrees and tested for 30 minutes.

The reel was then placed in the axis parallel to the test bed and tested for 30 minutes. After 30 minutes vibration the reel was turned 180 degrees and vibrated for 30 minutes.

At the conclusion of the 2 hour vibration test the sample was inspected for evidence of visible physical damage and none was observed.

Remarks: The reel of Fiber Optic Cable was returned to ITT for complete inspection and test evaluation.

5

# AEROSPACE RESEARCH CORPORATION
## TEST DATA

CUSTOMER ITT, Electro-Optical Products TEST ITEM Fiber Optic Cable (1 reel)

TEST SPECIFICATION Doc. Id No. 80-29-09, Revision II

PARAGRAPH NUMBER 4.6 PART NUMBER

SERIAL NUMBER #8

TEST TITLE Vibration Test (Secured Cargo)

P.O. NUMBER 34395 TEST CONDUCTED BY S.D. Bernard

DATE 9-16-81 TEST TEMP. +79 °F ROOM TEMP. +79 °F BAROMETRIC PRESSURE 28.93 In. Hg.

The Secured Cargo Vibration Test was conducted in accordance with Preproduction Test Procedure for Ruggedized Tactical Fiber Optic Cable Document Identification number 80-29-09, Revision II.

The test sample was mounted on the vibration exciter and subjected to the following secured cargo vibration test in the lateral and longitudinal axes. The vibration time was 84 minutes per axis. The sweep time from 6 to 200 to 6 Hz was 12 minutes.

| Frequency, Hz | G level |
|---|---|
| 6 - 200 | 1.5 |

At the conclusion of the vibration test the sample was inspected for evidence of visible physical damage and none was observed.

CERTIFICATION

We certify that this test data is a true report on our Vibration Tests (Secured Cargo, and Loose Cargo) on one reel Fiber Optic Cable, submitted by ITT, Electro-Optical Products Division, Roanoke, Virginia. Calibration of our instrumentation is traceable to the National Bureau of Standards.

Respectfully submitted,

AEROSPACE RESEARCH CORPORATION

Leslie C. Rose

Leslie C. Rose
Vice President

Subscribed and sworn to before me this 18th day of September, 1981.

Betty C. Fitzpatrick My commission expires July 16, 1984.
Notary Public

# APPENDIX E

# TEMPERATURE SHOCK TEST DATA

Table E-1. Temperature Shock Test Cable Results, Cable 2 and Cable 5.

| Fiber id | | Attenuation (dB/km) Before | After | Δ | Dispersion (ns/km) Before | After | Δ |
|---|---|---|---|---|---|---|---|
| **Cable 2: 071881-4C-1** | | | | | | | |
| 1 | Blue | 3.61 | 3.98 | +0.37 | 1.08 | 1.05 | -0.03 |
| 2 | Orange | 3.46 | 3.58 | +0.12 | 0.80 | 0.96 | +0.16 |
| 3 | Brown | 3.09 | 3.30 | +0.21 | 0.78 | 0.75 | -0.03 |
| 4 | White | 2.95 | 3.09 | +0.14 | 1.01 | 1.07 | +0.06 |
| 5 | Slate | 3.14 | 3.33 | +0.19 | 1.20 | 1.29 | +0.09 |
| 6 | Green | 3.29 | 3.54 | +0.25 | 0.63 | 0.54 | -0.09 |
| | Average | 3.26 | 3.47 | +0.21 | 0.91 | 0.94 | +0.03 |
| **Cable 5: 072081-4C-1** | | | | | | | |
| 1 | Blue | 4.27 | 3.31 | -0.96 | 0.11 | 0.96 | +0.85 |
| 2 | Orange | 3.50 | 3.37 | -0.13 | 1.21 | 1.29 | +0.08 |
| 3 | Brown | 2.26 | 3.32 | +1.06 | 1.52 | 1.12 | -0.40 |
| 4 | White | 3.38 | 3.37 | -0.01 | 0.92 | 0.91 | -0.01 |
| 5 | Slate | 3.62 | 3.45 | -0.17 | 1.24 | 1.35 | +0.11 |
| 6 | Green | 3.39 | 4.21 | +0.82 | 0.52 | 0.64 | +0.12 |
| | Average | 3.40 | 3.50 | +0.10 | 0.92 | 1.04 | +0.12 |

Table E-2. Temperature Shock Test Cable Results, Cable 6 and Cable 7.

| Fiber id | | Attenuation (dB/km) Before | Attenuation (dB/km) After | Attenuation (dB/km) Δ | Dispersion (ns/km) Before | Dispersion (ns/km) After | Dispersion (ns/km) Δ |
|---|---|---|---|---|---|---|---|
| **Cable 6: 071681-4C-1** | | | | | | | |
| 1 | Blue | 3.30 | 3.50 | +0.20 | 0.76 | 0.69 | -0.06 |
| 2 | Orange | 3.50 | 3.30 | -0.20 | 0.73 | 0.63 | -0.10 |
| 3 | Brown | 3.45 | 3.57 | +0.12 | 0.52 | 0.49 | -0.03 |
| 4 | White | 4.14 | 3.21 | -0.93 | 0.66 | 0.59 | -0.07 |
| 5 | Slate | 3.08 | 3.21 | +0.13 | 0.71 | 0.69 | -0.02 |
| 6 | Green | 3.90 | 3.87 | -0.03 | 0.74 | 0.55 | -0.19 |
| | Average | 3.56 | 3.44 | -0.12 | 0.69 | 0.61 | -0.08 |
| **Cable 7: 072081-4C-2** | | | | | | | |
| 1 | Blue | 3.90 | 3.46 | -0.44 | 0.97 | 0.97 | 0.00 |
| 2 | Orange | 3.84 | 3.49 | -0.25 | 1.26 | 1.48 | +0.22 |
| 3 | Brown | 4.32 | 4.20 | -0.12 | 0.44 | 0.43 | -0.01 |
| 4 | White | 3.42 | 3.67 | +0.25 | 1.22 | 1.21 | -0.01 |
| 5 | Slate | 4.40 | 4.40 | 0.00 | 1.02 | 0.64 | -0.38 |
| 6 | Green | 4.32 | 3.57 | -0.75 | 0.65 | 0.61 | -0.04 |
| | Average | 4.03 | 3.81 | -0.22 | 0.93 | 0.89 | -0.04 |

Table E-3. Attenuation Versus Wavelength* (dB/km) After Temperature Shock Test.

Cable 2: 071881-4C-1

| Fiber | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| | Wavelength (nm) | | | | | |
| 1 Blue | 4.56 | 3.98 | 1.95 | 1.77 | 1.50 | 1.43 |
| 2 Orange | 4.01 | 3.58 | 1.76 | 1.64 | 1.38 | 1.49 |
| 3 Brown | 3.83 | 3.30 | 1.70 | 1.59 | 1.39 | 1.38 |
| 4 White | 3.56 | 3.09 | 1.43 | 1.37 | 1.17 | 1.20 |
| 5 Slate | 3.58 | 3.33 | 1.56 | 1.40 | 1.13 | 1.36 |
| 6 Green | 3.93 | 3.54 | 1.8 | 1.63 | 1.35 | 1.36 |

Cable 5: 072081-4C-1

| Fiber | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| Blue | 3.73 | 3.31 | 1.51 | 1.37 | 1.09 | 1.20 |
| Orange | 3.84 | 3.37 | 1.65 | 1.62 | 1.40 | 1.47 |
| Brown | 3.75 | 3.32 | 1.74 | 1.60 | 1.48 | 1.42 |
| White | 3.81 | 3.37 | 1.53 | 1.38 | 1.12 | 1.03 |
| [illegible] | 4.03 | 3.45 | 1.52 | 1.32 | 1.07 | 1.03 |
| [illegible] | 4.66 | 4.21 | 2.68 | 2.59 | 2.50 | 2.60 |

*[illegible]

AD-A120 780 MANUFACTURING METHODS AND TECHNOLOGY PROGRAM FOR RUGGEDIZED TACTICAL FIBE..(U) ITT ELECTRO-OPTICAL PRODUCTS DIV ROANOKE VA D TAYLOR OCT 81 ITT-81-42-05A 2/2

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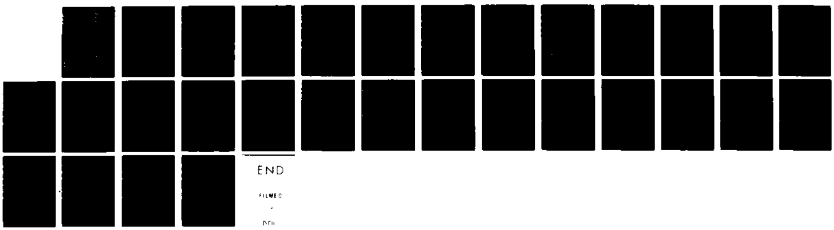

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Table E-3. Attenuation Versus Wavelength* (dB/km) After Temperature Shock Test (continued).

Cable 6: 071681-4C-1

| Fiber | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 4.05 | 3.50 | 1.65 | 1.52 | 1.28 | 1.42 |
| 2 Orange | 3.76 | 3.30 | 1.82 | 1.65 | 1.20 | 1.25 |
| 3 Brown | 3.93 | 3.57 | 1.91 | 1.82 | 1.84 | 3.51 |
| 4 White | 3.61 | 3.21 | 1.49 | 1.32 | 1.07 | 1.13 |
| 5 Slate | 3.72 | 3.21 | 1.51 | 1.38 | 1.15 | 1.24 |
| 6 Green | 4.51 | 3.87 | 2.98 | 1.65 | 1.35 | 1.25 |

Cable 7: 072081-4C-2

| Fiber | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 4.02 | 3.46 | 1.60 | 1.46 | 1.21 | 1.20 |
| 2 Orange | 4.04 | 3.49 | 1.67 | 1.46 | 1.22 | 1.14 |
| 3 Brown | 4.69 | 4.20 | 2.19 | 2.05 | 1.75 | 4.64 |
| 4 White | 4.22 | 3.67 | 1.75 | 1.64 | 1.38 | 1.68 |
| 5 Slate | 4.90 | 4.40 | 2.29 | 2.11 | 1.77 | 1.79 |
| 6 Green | 4.01 | 3.57 | 1.83 | 1.75 | 1.49 | 1.48 |

*Injected NA 0.089.

Table E-4. Attenuation Versus Injected NA After Temperature Shock (Wavelength 820 nm).

Cable 2: 071881-4C-1

| Fiber | | Injection NA 0.089 | 0.124 | 0.176 | 0.243 |
|---|---|---|---|---|---|
| 1 | Blue | 4.56 | 4.74 | 4.52 | 4.74 |
| 2 | Orange | 4.01 | 3.97 | 4.16 | 4.30 |
| 3 | Brown | 3.83 | 3.79 | 3.83 | 3.84 |
| 4 | White | 3.56 | 3.56 | 3.84 | 3.88 |
| 5 | Slate | 3.58 | 3.68 | 3.97 | 3.82 |
| 6 | Green | 3.93 | 4.41 | 4.21 | 4.33 |

Cable 5: 072081-4C-1

| Fiber | | 0.089 | 0.124 | 0.176 | 0.243 |
|---|---|---|---|---|---|
| 1 | Blue | 3.73 | 3.74 | 4.02 | 4.11 |
| 2 | Orange | 3.84 | 3.62 | 3.69 | 3.97 |
| 3 | Brown | 3.75 | 3.57 | 3.81 | 3.70 |
| 4 | White | 3.81 | 3.94 | 4.15 | 4.29 |
| 5 | Slate | 4.03 | 3.94 | 4.27 | 4.28 |
| 6 | Green | 4.66 | 4.65 | 4.86 | 5.24 |

Table E-4. Attenuation Versus Injected NA After Temperature Shock (Wavelength 820 nm) (continued).

**Cable 6: 071681-4C-1**

| | | Injection NA | | | |
|---|---|---|---|---|---|
| Fiber | | 0.089 | 0.124 | 0.176 | 0.243 |
| 1 | Blue | 4.05 | 4.00 | 4.26 | 4.13 |
| 2 | Orange | 3.76 | 3.69 | 3.90 | 4.00 |
| 3 | Brown | 3.93 | 4.01 | 4.06 | 4.03 |
| 4 | White | 3.61 | 4.22 | 3.82 | 4.00 |
| 5 | Slate | 3.72 | 3.75 | 3.83 | 3.90 |
| 6 | Green | 4.51 | 4.39 | 4.63 | 4.62 |

**Cable 7: 072081-4C-2**

| | | | | | |
|---|---|---|---|---|---|
| 1 | Blue | 4.02 | 4.20 | 4.27 | 4.35 |
| 2 | Orange | 4.04 | 4.20 | 4.10 | 4.20 |
| 3 | Brown | 4.69 | 4.86 | 4.66 | 4.71 |
| 4 | White | 4.22 | 4.25 | 4.37 | 4.55 |
| 5 | Slate | 4.90 | 4.79 | 4.76 | 4.90 |
| 6 | Green | 4.01 | 4.18 | 4.21 | 4.40 |

Table E-5. Numerical Aperture (90% Power) After Temperature Shock.

| | | Cable Number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fiber | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | Blue | | 0.21 | | | 0.20 | 0.25 | 0.22 | | | | | |
| 2 | Orange | | 0.24 | | | 0.21 | 0.24 | 0.22 | | | | | |
| 3 | Brown | | 0.23 | | | 0.20 | 0.21 | 0.25 | | | | | |
| 4 | White | | 0.25 | | | 0.22 | 0.23 | 0.21 | | | | | |
| 5 | Slate | | 0.23 | | | 0.22 | 0.22 | 0.21 | | | | | |
| 5 | Green | | 0.23 | | | 0.20 | 0.21 | 0.24 | | | | | |

## APPENDIX F

## FINISHED CABLE TEST DATA

Table F-1. Finished Cable Test Results, MM&T Cables (Confirmatory).

| CABLE | IMPACT TEST | 3-FT-LB | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ROOM TEMPERATURE | | | | | +71C | | | | | -55C | | | |
| | S | BF | % SF | JS | | S | BF | % SF | JS | | S | BF | % SF | JS |
| 3[B] 071881-4C-2 | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 | | 6 | 6 | 85 | 0 |
| 5[B] 072081-4C-1 | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 | | 6 | 6 | 85 | 0 |
| 7[B] 072081-4C-2 | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 | | 6 | 5 | 86 | 0 |
| | | | | | BEND | TEST | | LOAD | MASS = | 10 KG | BEND | RADIUS | = 1.27 | CM |
| 3[B] 071881-4C-2 | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 |
| 5[B] 072081-4C-1 | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 |
| 7[B] 072081-4C-2 | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 |
| | | | | | TWIST | TEST | | LOAD MASS = 10 KG | | | PULLEY | CENTER | DIA = | 3.175 CM |
| 3[B] 071881-4C-2 | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 |
| 5[B] 072081-4C-1 | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 |
| 7[B] 072081-4C-2 | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 | | 6 | 0 | 100 | 0 |

004-095 WHERE: S = NO OF SAMPLE TESTED
BF = NO OF BROKEN FIBERS

% SF = PERCENT OF SURVIVING FIBERS = $\frac{S \times 6 - BF}{S \times 6} \times 100$

JS = JAKET SPLIT

II-3.1 TENSILE LOAD

Cable 071881-4a-1 #3

Sample Length ______________ m

Gage Length 86 m

Starting Tensile Load(t=0) 410 $lb_f$

$(1\ lb_f = 4.448\ N)$ 1823 N

**Specification**

400 min

1780 min

Adjustments During Test

| Approximate Time s | Initial Load lbf | Adjusted Load lbf |
|---|---|---|
| 15 | 380 | 400 |
| * 45 | 395 | 410 |
| | | |

Finished Tensile Load (t=60s) 410 $lb_f$

Post Test Continuity 1823 N

| Number of Continuous Fibers | Specification |
|---|---|
| 6 | 6 |

Remarks: * Adjusted prematurely
observed by Tom Armstrong. T. G. Armstrong 9/17/81
Gauge calibrated 9/3/81

Pass ✓ Fail ______

Operator B. Fagis

Date 09/17/81

Government Witness ______________

Date ______________

II-3.1 TENSILE LOAD

Cable 072081-4c-1 #5

Sample Length ____________ m

Gage Length 7.2 (3.6x2) m

| | | Specification |
|---|---|---|
| Starting Tensile Load(t=0) | 820/2 = 410 $lb_f$ | 400 min |
| ($1\ lb_f = 4.448$ N) | 1823 N | 1780 min |

Adjustments During Test

| Approximate Time s | Initial Load $lb_f$ | Adjusted Load $lb_f$ |
|---|---|---|
| 15 | 380 | 410 |
| 50 | 380 | 405 |

Finished Tensile Load (t=60s) 402 $lb_f$

Post Test Continuity 1788 N

| Number of Continuous Fibers | Specification |
|---|---|
| 6 | 6 |

Remarks:

OBSERVED BY MIKE BOWMAN, MfBowman

GAUGE CHATILLON MODEL WT-10 SERIAL 4389 (ITT 781 7908)

Pass ✓ Fail ____

Operator R. FARIS

Date 8-26-81

Government Witness ____________

Date ____________

cable #7

II-3.1 TENSILE LOAD

Cable 072081-4C-2

Sample Length ________ m

Gage Length 7.36 (3.68x2) m

Starting Tensile Load($\tau$=0) 425 $lb_f$

(1 $lb_f$ = 4.448 N) ________ N

Specification

400 min

1780 min

Adjustments During Test

| Approximate Time s | Initial Load $lb_f$ | Adjusted Load $lb_f$ |
|---|---|---|
| 10 | 850 | — |
| | | |

Finished Tensile Load ($\tau$=60s) 370 $lb_f$

Post Test Continuity ________ N

| Number of Continuous Fibers | Specification |
|---|---|
| 6 | 6 |

Remarks: DC-[illegible] 10/16/81

Pass ✓ Fail ________

Operator: [signature]

Date 10/16/87

Government Witness ________

Date ________

# APPENDIX G

# TEMPERATURE CYCLING DATA

Table G-1. High and Low Temperature Test Results, Cable 1 and Cable 2.

**Cable 1: 071781-4C-1**

| | | Attenuation (dB/km) | | | Dispersion (ns/km) | | | High Temp ($\Delta$dB/km) | | Low Temp ($\Delta$dB/km) |
|---|---|---|---|---|---|---|---|---|---|---|
| Fiber id | | Before | After | $\Delta$ | Before | After | $\Delta$ | +49°C | +71°C | -55°C |
| 1 | Blue | 3.65 | 3.09 | -0.56 | 0.36 | 0.37 | +0.01 | 0.09 | 0.19 | 1.60 |
| 2 | Orange | 3.65 | 3.25 | -0.40 | 0.36 | 0.51 | +0.15 | 0.06 | 0.17 | 4.77 |
| 3 | Brown | 3.14 | 3.07 | -0.07 | 0.93 | 1.09 | +0.16 | 0.17 | 0.24 | 3.90 |
| 4 | White | 2.94 | 2.55 | -0.39 | 0.52 | 1.52 | +1.00 | 0.05 | 0.06 | 0.87 |
| 5 | Slate | 3.43 | 3.15 | -0.28 | 0.76 | 1.35 | +0.59 | 0.18 | 0.11 | 2.55 |
| 6 | Green | 3.42 | 3.30 | -0.12 | 0.33 | 0.52 | +0.19 | 0.21 | 0.28 | 1.68 |
| | Average | 3.37 | 3.07 | -0.30 | 0.54 | 0.89 | +0.35 | 0.13 | 0.18 | 2.56 |

**Cable 2: 071881-4C-1**

| | | Attenuation (dB/km) | | | Dispersion (ns/km) | | | High Temp ($\Delta$dB/km) | | Low Temp ($\Delta$dB/km) |
|---|---|---|---|---|---|---|---|---|---|---|
| Fiber id | | Before | After | $\Delta$ | Before | After | $\Delta$ | +49°C | +71°C | -55°C |
| 1 | Blue | 4.22 | 3.61 | -0.61 | 0.94 | 1.08 | +0.14 | 0.05 | 0.06 | 1.44 |
| 2 | Orange | 3.68 | 3.46 | -0.22 | 0.77 | 0.80 | +0.03 | 0.01 | 0.02 | 1.47 |
| 3 | Brown | 3.04 | 3.09 | +0.05 | 0.72 | 0.78 | +0.06 | 0.09 | 0.08 | 2.58 |
| 4 | White | 3.32 | 2.95 | -0.37 | 0.84 | 1.01 | +0.17 | 0.04 | 0.05 | 1.81 |
| 5 | Slate | 3.87 | 3.14 | -0.73 | 1.39 | 1.20 | -0.19 | 0.05 | 0.04 | 0.59 |
| 6 | Green | 2.84 | 3.29 | +0.45 | 0.48 | 0.63 | +0.15 | 0.01 | 0.00 | 2.03 |
| | Average | 3.49 | 3.26 | -0.23 | 0.85 | 0.91 | +0.06 | 0.04 | 0.04 | 1.65 |

Table G-2. High and Low Temperature Test Results, Cable 3 and Cable 4.

| Fiber id | | Attenuation (dB/km) Before | After | Δ | Dispersion (ns/km) Before | After | Δ | High Temp (ΔdB/km) +49°C | +71°C | Low Temp (ΔdB/km) -55°C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Cable 3: 071881-4C-2** | | | | | |
| 1 | Blue | 3.29 | 3.23 | -0.06 | 0.44 | 0.55 | +0.11 | 0.04 | 0.02 | 10.12 |
| 2 | Orange | 3.15 | 3.40 | +0.25 | 0.31 | 0.52 | +0.21 | 0.11 | 0.14 | 5.72 |
| 3 | Brown | 3.34 | 3.15 | -0.19 | 0.68 | 0.55 | -0.13 | 0.04 | 0.09 | 2.72 |
| 4 | White | 3.20 | 3.56 | +0.36 | 0.60 | 0.50 | -0.10 | 0.00 | 0.01 | 2.03 |
| 5 | Slate | 3.23 | 4.11 | +0.88 | 0.34 | 0.67 | +0.33 | 0.10 | 0.16 | 1.50 |
| 6 | Green | 3.47 | 3.93 | +0.46 | 1.03 | 1.20 | +0.17 | 0.01 | 0.03 | 1.43 |
| | Average | 3.28 | 3.56 | +0.28 | 0.56 | 0.66 | +0.10 | 0.05 | 0.08 | 3.93 |
| | | | | | **Cable 4: 071881-4C-3** | | | | | |
| 1 | Blue | 3.52 | 3.65 | +0.13 | 1.09 | 1.19 | +0.10 | 0.02 | 0.07 | 2.85 |
| 2 | Orange | 3.74 | 3.72 | -0.02 | 0.35 | 0.37 | +0.02 | 0.01 | 0.07 | 2.95 |
| 3 | Brown | 3.13 | 3.25 | +0.12 | 0.62 | 0.68 | +0.06 | 0.01 | 0.05 | 2.52 |
| 4 | White | 3.40 | 3.18 | -0.22 | 1.22 | 1.39 | +0.17 | 0.09 | 0.14 | 5.54 |
| 5 | Slate | 3.44 | 3.34 | -0.10 | 0.56 | 0.58 | +0.02 | 0.07 | 0.01 | 3.10 |
| 6 | Green | 3.31 | 3.42 | +0.11 | 0.56 | 0.51 | -0.05 | 0.04 | 0.09 | 1.33 |
| | Average | 3.42 | 3.42 | 0.00 | 0.73 | 0.78 | +0.05 | 0.04 | 0.07 | 3.04 |

Table G-3. High and Low Temperature Test Results, Cable 5 and Cable 6.

| Fiber id | | Attenuation (dB/km) | | | Dispersion (ns/km) | | | High Temp (ΔdB/km) | | Low Temp (ΔdB/km) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Before | After | Δ | Before | After | Δ | +49°C | +71°C | -55°C |
| **Cable 5: 072081-4C-1** | | | | | | | | | | |
| 1 | Blue | 4.53 | 4.27 | -0.26 | 0.76 | 0.11 | -0.65 | 0.02 | 0.02 | 2.08 |
| 2 | Orange | 3.50 | 3.50 | 0.00 | 1.37 | 1.21 | -0.16 | 0.16 | 0.25 | 0.61 |
| 3 | Brown | 3.38 | 2.26 | -1.12 | 1.46 | 1.52 | +0.06 | 0.03 | 0.03 | 2.04 |
| 4 | White | 3.66 | 3.38 | -0.28 | 0.98 | 0.92 | -0.06 | 0.06 | 0.13 | 3.66 |
| 5 | Slate | 3.63 | 3.62 | -0.01 | 1.61 | 1.24 | -0.37 | 0.09 | 0.08 | 2.29 |
| 6 | Green | 3.43 | 3.39 | -0.04 | 0.68 | 0.52 | -0.16 | 0.04 | 0.03 | 1.46 |
| | Average | 3.69 | 3.40 | -0.29 | 1.14 | 0.92 | -0.22 | 0.06 | 0.09 | 2.02 |
| **Cable 6: 071681-4C-1** | | | | | | | | | | |
| 1 | Blue | 3.21 | 3.30 | +0.09 | 0.32 | 0.76 | +0.44 | 0.04 | 0.06 | 12.65 |
| 2 | Orange | 3.14 | 3.50 | +0.36 | 0.72 | 0.73 | +0.01 | 0.08 | 0.13 | 6.59 |
| 3 | Brown | 3.08 | 3.45 | +0.37 | 0.51 | 0.52 | +0.01 | 0.08 | 0.15 | 2.93 |
| 4 | White | 2.82 | 4.14 | +1.32 | 0.21 | 0.66 | +0.45 | 0.08 | 0.11 | 3.62 |
| 5 | Slate | 2.94 | 3.08 | +0.14 | 0.69 | 0.71 | +0.02 | 0.02 | 0.01 | 3.47 |
| 6 | Green | 4.07 | 3.90 | -0.17 | 0.65 | 0.74 | +0.09 | 0.24 | 0.24 | 6.40 |
| | Average | 3.21 | 3.56 | +0.35 | 0.52 | 0.69 | +0.17 | 0.09 | 0.12 | 5.94 |

Table G-4. High and Low Temperature Test Results, Cable 7 and Cable 8.

**Cable 7: 072081-4C-2**

| Fiber id | | Attenuation (dB/km) Before | Attenuation (dB/km) After | Attenuation (dB/km) Δ | Dispersion (ns/km) Before | Dispersion (ns/km) After | Dispersion (ns/km) Δ | High Temp (ΔdB/km) +49°C | High Temp (ΔdB/km) +71°C | Low Temp (ΔdB/km) -55°C |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Blue | 3.42 | 3.90 | +0.48 | 1.00 | 0.97 | +0.03 | 0.05 | 0.07 | 2.31 |
| 2 | Orange | 3.40 | 3.84 | +0.44 | 1.22 | 1.26 | +0.04 | 0.05 | 0.09 | 4.74 |
| 3 | Brown | 4.18 | 4.32 | +0.14 | 0.37 | 0.44 | +0.07 | 0.05 | 0.09 | 4.92 |
| 4 | White | 3.34 | 3.42 | +0.08 | 0.87 | 1.22 | +0.35 | 0.06 | 0.15 | 2.36 |
| 5 | Slate | 4.11 | 4.40 | +0.29 | 0.69 | 1.02 | +0.33 | 0.00 | 0.04 | 9.27 |
| 6 | Green | 3.73 | 4.32 | +0.59 | 0.57 | 0.65 | +0.08 | 0.03 | 0.04 | 2.70 |
| | Average | 3.69 | 4.03 | +0.34 | 0.79 | 0.93 | +0.15 | 0.04 | 0.08 | 4.38 |

**Cable 8: 082781-4C-1**

| Fiber id | | Attenuation (dB/km) Before | Attenuation (dB/km) After | Attenuation (dB/km) Δ | Dispersion (ns/km) Before | Dispersion (ns/km) After | Dispersion (ns/km) Δ | High Temp (ΔdB/km) +49°C | High Temp (ΔdB/km) +71°C | Low Temp (ΔdB/km) -55°C |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Blue | 3.31 | 4.07 | +0.76 | 1.45 | 1.80 | +0.35 | 0.05 | 0.09 | 1.28 |
| 2 | Orange | 2.95 | 2.81 | -0.14 | 0.81 | 0.75 | -0.06 | 0.60 | 0.74 | 4.77 |
| 3 | Brown | 3.29 | 3.06 | -0.23 | 0.62 | 0.48 | -0.14 | 0.14 | 0.19 | 2.04 |
| 4 | White | 3.62 | 3.46 | -0.16 | 1.41 | 1.22 | -0.19 | 0.07 | 0.12 | 3.48 |
| 5 | Slate | 3.94 | 3.32 | -0.62 | 1.16 | 0.86 | -0.30 | 0.22 | 0.43 | 1.38 |
| 6 | Green | 3.87 | 3.62 | -0.25 | 0.66 | 0.74 | +0.08 | 0.04 | 0.08 | 1.74 |
| | Average | 3.50 | 3.40 | -0.10 | 1.01 | 0.97 | -0.04 | 0.18 | 0.27 | 2.44 |

Table G-5. High and Low Temperature Test Results, Cable 10 and Cable 12.

| Fiber id | | Attenuation (dB/km) | | | Dispersion (ns/km) | | | High Temp (ΔdB/km) | | Low Temp (ΔdB/km) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Before | After | Δ | Before | After | Δ | +49°C | +71°C | -55°C |
| **Cable 10: 091881-4C-2** | | | | | | | | | | |
| 1 | Blue | 3.64 | 3.73 | +0.09 | 1.05 | 0.95 | -0.10 | 0.33 | 0.39 | 1.59 |
| 2 | Orange | 3.34 | 3.58 | +0.24 | 1.00 | 1.71 | +0.71 | 0.49 | 0.44 | 2.26 |
| 3 | Brown | 4.30 | 4.26 | -0.04 | 0.43 | 1.16 | +0.73 | 0.37 | 0.42 | 2.48 |
| 4 | White | 2.96 | 3.82 | +0.86 | 1.04 | 1.08 | +0.04 | 2.03 | 2.08 | 4.20 |
| 5 | Slate | 4.01 | 3.77 | -0.24 | 0.52 | 0.58 | +0.06 | -0.11 | -0.06 | 1.76 |
| 6 | Green | 3.67 | 3.50 | -0.17 | 1.49 | 1.49 | 0.00 | 0.12 | 0.21 | 1.62 |
| | Average | 3.65 | 3.77 | +0.12 | 0.92 | 1.16 | +0.24 | 0.53 | 0.58 | 2.31 |
| **Cable 12: 091781-4C-1** | | | | | | | | | | |
| 1 | Blue | 4.19 | 4.15 | -0.04 | 0.70 | 0.39 | -0.31 | 0.06 | 0.19 | 11.22 |
| 2 | Orange | 3.03 | 2.78 | -0.26 | 1.20 | 0.78 | -0.42 | 0.01 | 0.05 | 0.43 |
| 3 | Brown | 3.00 | 3.04 | +0.04 | 0.72 | 0.31 | -0.41 | 0.16 | 0.33 | 21.46 |
| 4 | White | 3.37 | 3.40 | +0.03 | 0.70 | 0.78 | +0.08 | 0.02 | 0.16 | 4.03 |
| 5 | Slate | 3.70 | 2.92 | -0.78 | 1.18 | 1.04 | -0.14 | 0.03 | 0.20 | 2.37 |
| 6 | Green | 3.03 | 3.28 | +0.25 | 0.71 | 0.52 | -0.19 | -0.06 | 0.04 | 3.84 |
| | Average | 3.38 | 3.26 | -0.12 | 0.86 | 0.63 | -0.23 | 0.04 | 0.16 | 7.22 |

Table G-6. Attenuation Versus Wavelength* (dB/km) After Temperature Cycling.

Cable 1: 071781-4C-1

| Fiber | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 3.55 | 3.14 | 1.47 | 1.35 | 1.13 | 1.19 |
| 2 Orange | 3.36 | 2.94 | 1.36 | 1.22 | 0.98 | 1.05 |
| 3 Brown | 3.80 | 3.36 | 1.74 | 1.56 | 1.33 | 1.42 |
| 4 White | 3.89 | 3.38 | 3.06 | 1.43 | 1.21 | 1.28 |
| 5 Slate | 3.29 | 2.92 | 1.44 | 1.30 | 1.28 | 1.22 |
| 6 Green | 3.80 | 3.36 | 1.67 | 1.56 | 1.28 | 1.36 |

Cable 2: 071881-4C-1

| Fiber | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|
| 1 Blue | 4.21 | 3.63 | 1.60 | 1.43 | 1.24 | 1.04 |
| 2 Orange | 3.90 | 3.46 | 1.60 | 1.48 | 1.23 | 1.36 |
| 3 Brown | 3.57 | 3.09 | 1.51 | 1.34 | 1.22 | 1.11 |
| 4 White | 3.40 | 2.95 | 1.33 | 1.21 | 1.05 | 1.04 |
| 5 Slate | 3.49 | 3.14 | 1.37 | 1.21 | 0.96 | 1.11 |
| 6 Green | 3.75 | 3.29 | 1.49 | 4.13 | 1.57 | 1.08 |

*Injected NA 0.089.

Table G-6. Attenuation Versus Wavelength* (dB/km) After Temperature Cycling (continued).

Cable 3: 071881-4C-2

| Fiber | | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 3.68 | 3.23 | 1.60 | 1.46 | 1.22 | 1.17 |
| 2 | Orange | 3.79 | 3.29 | 1.61 | 1.43 | 1.43 | 3.35 |
| 3 | Brown | 3.78 | 3.26 | 1.56 | 1.41 | 1.19 | 1.22 |
| 4 | White | 3.90 | 3.30 | 1.53 | 1.35 | 1.03 | 0.94 |
| 5 | Slate | 3.63 | 3.12 | 1.46 | 1.34 | 1.08 | 1.13 |
| 6 | Green | 3.85 | 3.32 | 1.25 | 1.08 | 0.71 | 0.58 |

Cable 4: 071881-4C-3

| Fiber | | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 4.22 | 3.63 | 1.74 | 1.61 | 1.30 | 1.30 |
| 2 | Orange | 4.21 | 3.73 | 1.93 | 1.76 | 1.47 | 1.55 |
| 3 | Brown | 3.69 | 3.24 | 1.50 | 1.29 | 1.01 | 0.99 |
| 4 | White | 3.86 | 3.36 | 1.50 | 1.37 | 1.16 | 1.26 |
| 5 | Slate | 3.92 | 3.42 | 1.76 | 1.64 | 1.42 | 1.41 |
| 6 | Green | 3.91 | 3.45 | 1.77 | 1.62 | 1.35 | 1.32 |

*Injected NA 0.089.

Table G-6. Attenuation Versus Wavelength* (dB/km) After Temperature Cycling (continued).

**Cable 5: 072081-4C-1**

| Fiber | | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 4.64 | 4.27 | 2.54 | 2.38 | 2.05 | 2.08 |
| 2 | Orange | 4.02 | 3.50 | 1.70 | 1.53 | 1.93 | 1.18 |
| 3 | Brown | 3.24 | 2.26 | 1.48 | 1.54 | 1.30 | 1.22 |
| 4 | White | 3.86 | 3.38 | 1.64 | 1.51 | 1.23 | 1.19 |
| 5 | Slate | 4.05 | 3.62 | 1.66 | 1.53 | 1.25 | 1.21 |
| 6 | Green | 3.85 | 3.39 | 1.70 | 1.56 | 1.36 | 1.28 |

**Cable 6: 071681-4C-1**

| Fiber | | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 3.90 | 3.30 | 1.55 | 1.39 | 1.16 | 1.19 |
| 2 | Orange | 3.78 | 3.50 | 1.71 | 1.57 | 1.79 | 1.22 |
| 3 | Brown | 3.95 | 3.45 | 1.85 | 1.60 | 1.65 | 3.50 |
| 4 | White | 4.59 | 4.14 | 2.38 | 2.21 | 2.09 | 2.04 |
| 5 | Slate | 3.59 | 3.08 | 1.37 | 1.25 | 1.03 | 1.03 |
| 6 | Green | 4.61 | 3.90 | 1.77 | 1.66 | 1.35 | 1.22 |

*Injected NA 0.089.

Table G-6. Attenuation Versus Wavelength* (dB/km) After Temperature Cycling (continued).

Cable 7: 072081-4C-2

| Fiber | | Wavelength (nm) 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 3.95 | 3.37 | 1.49 | 1.31 | 1.06 | 0.99 |
| 2 | Orange | 4.07 | 3.56 | 1.67 | 1.57 | 1.27 | 0.80 |
| 3 | Brown | 4.71 | 4.28 | 2.31 | 2.16 | 1.83 | 1.86 |
| 4 | White | 3.85 | 3.32 | 1.43 | 1.35 | 1.14 | 1.49 |
| 5 | Slate | 4.71 | 4.13 | 2.06 | 1.89 | 1.54 | 1.52 |
| 6 | Green | 4.14 | 3.66 | 1.95 | 1.81 | 1.56 | 1.38 |

Cable 8: 082781-4C-1

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 4.66 | 4.07 | 2.54 | 2.24 | 2.29 | 3.96 |
| 2 | Orange | 3.35 | 2.81 | 1.38 | 1.22 | 0.96 | 1.00 |
| 3 | Brown | 3.77 | 3.06 | 1.51 | 1.32 | 1.01 | 1.11 |
| 4 | White | 3.71 | 3.46 | 1.52 | 1.46 | 1.18 | 1.13 |
| 5 | Slate | 4.01 | 3.32 | 1.42 | 1.31 | 1.01 | 1.14 |
| 6 | Green | 4.06 | 3.62 | 1.75 | 1.70 | 1.46 | 1.40 |

---

*Injected NA 0.089.

Table G-6. Attenuation Versus Wavelength* (dB/km) After Temperature Cycling (continued).

Cable 10: 091881-4C-2

| | Fiber | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| | | Wavelength (nm) | | | | | |
| 1 | Blue | 4.45 | 3.73 | 1.79 | 1.58 | 1.30 | 1.32 |
| 2 | Orange | 4.00 | 3.58 | 1.84 | 1.85 | 1.59 | 1.63 |
| 3 | Brown | 4.73 | 4.26 | 2.47 | 2.32 | 2.04 | 1.99 |
| 4 | White | 4.34 | 3.82 | 1.88 | 1.40 | 1.09 | 1.10 |
| 5 | Slate | 4.03 | 3.77 | 2.04 | 1.95 | 1.66 | 1.66 |
| 6 | Green | 4.02 | 3.50 | 1.61 | 1.47 | 1.31 | 1.45 |

Cable 12: 091781-4C-1A

| | Fiber | 820 | 850 | 1060 | 1100 | 1200 | 1300 |
|---|---|---|---|---|---|---|---|
| 1 | Blue | 4.59 | 4.15 | 2.26 | 1.83 | 1.75 | 1.79 |
| 2 | Orange | 3.18 | 2.78 | 1.28 | 1.19 | 1.00 | 0.93 |
| 3 | Brown | 3.50 | 3.04 | 1.51 | 1.42 | 1.20 | 0.65 |
| 4 | White | 3.91 | 3.40 | 1.70 | 1.55 | 1.32 | 1.23 |
| 5 | Slate | 3.39 | 2.92 | 1.38 | 1.25 | 1.11 | 1.10 |
| 6 | Green | 3.74 | 3.28 | 1.73 | 1.56 | 1.13 | 1.15 |

* Injected NA 0.089

Table G-7. Attenuation Versus Injected NA After Temperature Cycling (Wavelength 820 nm).

**Cable 1: 071781-4C-1**

| Fiber | Injection NA 0.089 | 0.124 | 0.176 | 0.243 |
|---|---|---|---|---|
| 1 Blue | 3.55 | 3.34 | 3.09 | 2.80 |
| 2 Orange | 3.36 | 3.13 | 2.58 | 2.48 |
| 3 Brown | 3.80 | 3.89 | 4.04 | 4.19 |
| 4 White | 3.89 | 3.93 | 3.95 | 4.08 |
| 5 Slate | 3.29 | 3.93 | 4.26 | 3.33 |
| 6 Green | 3.80 | 3.69 | 3.99 | 3.96 |

**Cable 2: 071881-4C-1**

| Fiber | 0.089 | 0.124 | 0.176 | 0.243 |
|---|---|---|---|---|
| 1 Blue | 4.21 | 4.33 | 4.48 | 4.44 |
| 2 Orange | 3.90 | 3.89 | 4.05 | 4.25 |
| 3 Brown | 3.57 | 3.70 | 4.61 | 3.68 |
| 4 White | 3.40 | 3.47 | 3.60 | 3.74 |
| 5 Slate | 3.49 | 3.50 | 3.63 | 3.78 |
| 6 Green | 3.75 | 3.75 | 3.94 | 4.18 |

Table G-7. Attenuation Versus Injected NA After Temperature Cycling (Wavelength 820 nm) (continued).

Cable 3: 071881-4C-2

| Fiber | | Injection NA 0.089 | 0.124 | 0.176 | 0.243 |
|---|---|---|---|---|---|
| 1 | Blue | 3.68 | 3.71 | 3.47 | 3.18 |
| 2 | Orange | 3.79 | 4.01 | 3.81 | 3.94 |
| 3 | Brown | 3.78 | 4.06 | 4.26 | 4.35 |
| 4 | White | 3.90 | 4.20 | 4.23 | 4.21 |
| 5 | Slate | 3.63 | 3.51 | 3.65 | 3.80 |
| 6 | Green | 3.85 | 4.01 | 4.11 | 4.37 |

Cable 4: 071881-4C-3

| Fiber | | Injection NA 0.089 | 0.124 | 0.176 | 0.243 |
|---|---|---|---|---|---|
| 1 | Blue | 4.09 | 3.96 | 4.54 | 4.22 |
| 2 | Orange | 4.21 | 4.30 | 4.37 | 4.22 |
| 3 | Brown | 3.69 | 3.79 | 3.76 | 4.02 |
| 4 | White | 3.86 | 3.86 | 3.85 | 3.91 |
| 5 | Slate | 3.92 | 3.97 | 4.05 | 4.24 |
| 6 | Green | 3.91 | 4.12 | 4.15 | 4.21 |

Table G-7. Attenuation Versus Injected NA After Temperature Cycling (Wavelength 820 nm) (continued).

**Cable 5: 072081-4C-1**

| | | Injection NA | | | |
|---|---|---|---|---|---|
| **Fiber** | | **0.089** | **0.124** | **0.176** | **0.243** |
| 1 | Blue | 4.64 | 4.49 | 4.48 | 4.33 |
| 2 | Orange | 4.02 | 4.08 | 4.21 | 4.23 |
| 3 | Brown | 3.24 | 6.94 | 3.40 | 3.53 |
| 4 | White | 3.86 | 3.76 | 3.92 | 4.08 |
| 5 | Slate | 4.05 | 4.02 | 4.11 | 4.06 |
| 6 | Green | 3.85 | 3.84 | 4.08 | 4.17 |

**Cable 6: 071681-4C-1**

| | | | | | |
|---|---|---|---|---|---|
| 1 | Blue | 3.90 | 4.03 | 4.03 | 4.11 |
| 2 | Orange | 3.78 | 3.93 | 4.16 | 4.42 |
| 3 | Brown | 3.95 | 3.98 | 4.10 | 4.36 |
| 4 | White | 4.59 | 4.50 | 4.17 | 4.20 |
| 5 | Slate | 3.59 | 3.53 | 3.63 | 3.90 |
| 6 | Green | 4.61 | 4.55 | 4.61 | 4.72 |

Table G-7. Attenuation Versus Injected NA After Temperature Cycling (Wavelength 820 nm) (continued).

**Cable 7: 072081-4C-2**

| Fiber | Injection NA 0.089 | 0.124 | 0.176 | 0.243 |
|---|---|---|---|---|
| 1 Blue | 3.95 | 4.08 | 4.01 | 4.38 |
| 2 Orange | 4.07 | 4.10 | 4.35 | 4.49 |
| 3 Brown | 4.71 | 4.78 | 4.80 | 4.87 |
| 4 White | 3.85 | 3.87 | 4.05 | 4.19 |
| 5 Slate | 4.71 | 4.76 | 4.85 | 4.89 |
| 6 Green | 4.14 | 4.19 | 4.26 | 4.63 |

**Cable 8: 082781-4C-1**

| Fiber | 0.089 | 0.124 | 0.176 | 0.243 |
|---|---|---|---|---|
| 1 Blue | 4.66 | 4.57 | 4.77 | 4.62 |
| 2 Orange | 3.35 | 3.71 | 3.65 | 3.85 |
| 3 Brown | 3.77 | 4.05 | 4.27 | 3.91 |
| 4 White | 3.71 | 3.80 | 4.18 | 4.16 |
| 5 Slate | 4.01 | 3.79 | 4.22 | 4.08 |
| 6 Green | 4.06 | 4.64 | 4.34 | 4.25 |

Table G-7. Attenuation Versus Injected NA After Temperature Cycling (Wavelength 820 nm) (continued).

**Cable 10: 091881-4C-2**

| | | Injection NA | | | |
|---|---|---|---|---|---|
| Fiber | | 0.089 | 0.124 | 0.176 | 0.243 |
| 1 | Blue | 4.45 | 4.34 | 4.44 | 4.53 |
| 2 | Orange | 4.00 | 3.88 | 4.33 | 3.93 |
| 3 | Brown | 4.73 | 4.84 | 5.14 | 5.25 |
| 4 | White | 4.34 | 4.80 | 4.67 | 4.80 |
| 5 | Slate | 4.03 | 3.79 | 4.49 | 4.54 |
| 6 | Green | 4.02 | 4.22 | 4.14 | 4.09 |

**Cable 12: 091781-4C-1A**

| | | | | | |
|---|---|---|---|---|---|
| 1 | Blue | 4.59 | 4.65 | 4.62 | 4.71 |
| 2 | Orange | 3.18 | 3.15 | 3.57 | 3.73 |
| 3 | Brown | 3.50 | 3.77 | 3.98 | 4.14 |
| 4 | White | 3.91 | 3.94 | 3.77 | 4.11 |
| 5 | Slate | 3.39 | 3.54 | 3.54 | 3.83 |
| 6 | Green | 3.74 | 3.55 | 3.80 | 3.85 |

# APPENDIX H

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